Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

J. F. KELLY, Editor

CONTENTS

Volume VI. April, 1929 Number IV.

Coming Meetings and Papers..... II

Editorial—Lubrication Questionnaire for Anti-Friction Bearings—By Special Bearings Committee, A. I. & S. E. E., F. D. Egan Chairman..... III

On the Mathematic Theory of the Cottrell Electric Precipitator—By A. W. Simon, Ph.D., Research Physicist, Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama.... 143

Starting Characteristics of Steel Mill Synchronous Motors—By H. H. Angel, Motor Control Specialist, Bethlehem Steel Company, Sparrows Point, Md. 147

Discussion, presented by L. A. Umansky, K. M. Raynor, F. O. Schnure, R. M. Fuller, W. H. Feldman, H. K. Hardcastle and W. B. Shirk..... 152

Heat Resisting Alloys and Their Use in the Steel Plant—By J. D. Corfield, Engineer, Michigan Steel Casting Company, Detroit, Michigan..... 157

Discussion, presented by Dr. John Unger, J. S. Huston, F. H. Loftus, M. H. Mawhinney, H. V. Flagg, T. B. Bechtel and A. L. Culbertson..... 162

The Isley Furnace Control—By G. A. Merkt, Engineer, Morgan Construction Company, Worcester, Mass..... 164

Discussion, presented by Kenneth C. McCutcheon, H. C. Seibert, W. B. Chapman, F. E. Leahy, J. L. Hott and J. S. Green 172

Certain Principles in the Extended Utilization of Blast Furnace Gas—By Owen R. Rice, Met. Engr., Freyn Engineering Company, Chicago, Ill..... 176

Items of Interest..... 182

List of Advertisers.....IV

Published Monthly by

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Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
Subscription Price $5.00 per Year. Single Copy 50c

Coming Meetings and Papers

PITTSBURGH DISTRICT SECTION

Saturday, April 20th, 1929 — Wiliam Penn Hotel

Technical Session, 3:00 P. M. — Informal Dinner, 6:00 P. M.

Symposium:

"LIMIT SWITCHES FOR ELECTRIC OVERHEAD TRAVELING CRANES."

1. Importance of Installation.
2. Operation.
3. Inspection and Tests.
4. Maintenance.

Radio Broadcast at 7:15, "SAFETY AS A FACTOR IN INDUSTRY," by Charles M. Schwab, Chairman, Bethlehem Steel Corporation.

PHILADELPHIA DISTRICT SECTION

Friday, May 3rd, 1929 — Inspection Trip

Philadelphia Works of the General Electric Company, 6901 Elmwood Avenue.

"Demonstration of 1,000,000 Volt Arc." Papers by prominent Engineers. Arc Welding, Inspection, Electrically Welded Building.

CHICAGO DISTRICT SECTION

April — Electric Power Club

Symposium:

"CRANES FOR STEEL MILLS."

Cleveland Crane & Engineering Co., Morgan Engineering Company, Shaw Crane Works, Harnischfeger Corporation, Shepard-Niles Crane and Hoist Corporation and Alliance Machine Company.

BIRMINGHAM DISTRICT SECTION

Saturday, April 27th, 1929

"ELECTRICAL ILLUMINATION WITH DEMONSTRATION," by D. H. Tuck, Elec. Engr., Holophane Company, New York, N. Y.

NATIONAL CONVENTION AND IRON AND STEEL EXPOSITION

June 17th to 21st, Inc. — William Penn Hotel, Pittsburgh

Papers covering Safety, Combustion, Mechanical and Electrical applications in the Iron and Steel Industry will be discussed.

Inspection Trip to the Jones & Laughlin Steel Corporation at Aliquippa, Pa.

Representative Manufacturers will exhibit their developments.

Tech. 50

EDITORIAL

To the Iron and Steel Industry—

United States and Canada.

Gentlemen:

The Special Bearings Committee of the Association of Iron and Steel Electrical Engineers are making a study and will prepare a tabulated report covering completely the Anti-Friction Bearing Problem for Mill Type Motors, which is to be presented at the June Convention of our Society.

In the various meetings held by this Committee many valuable suggestions have been received and have been tabulated. In order to make this particular study complete it has been decided to circularize the Steel Industry regarding Lubrication of Anti-Friction Bearings on Mill and Crane Motors.

We would kindly ask that the questions contained in the questionnaire be answered as fully as possible. All information received will be treated as confidential so far as mentioning any company's names is concerned.

Special Study Regarding Lubrication of Anti-Friction Bearings on Mill and Crane Motors

1. How often should ball or Roller Bearings in Mill Motors be lubricated when operating under more or less normal conditions?.....
2. How much grease should be added when motors are lubricated? Is there any definite way of determining how much grease to add and at what intervals? .....
3. Should the frequency of lubrication be increased when motors are working under abnormal conditions, such as subject to heat from outside source; or should this condition be taken care of by a different grade of grease?.....
4. To what extent is grease leakage experienced?..
5. What type of grease has been found the most suitable for Ball or Roller Bearing lubrication?..
6. Should standard specifications be provided for grease so as to arrive at Uniform Conditions?...
7. What methods are used to insure that only ball or Roller Bearing grease will be used for bearings? .....
8. How often should motor bearings be thoroughly flushed and cleaned of grease residue?.....
9. How often should bearings be disassembled for inspection of bearings and grease?.....
10. What is variation in temperature in which motor operates throughout a year? Is it practical to draw specifications for a grease that would suit all conditions?
11. Is it advisable to place the greasing of motors under one head to obtain uniformity of practice?
12. What system of greasing motors do you favor? Grease cup application or gun application?.....
13. Do you consider it advisable to occasionally overgrease Anti-Friction Bearings in order to partially flush out worn grease and cleanse the labyrinths of foreign substances that may have collected? .....
14. Is objectionable heating of bearings experienced on account of over-greasing?.....

Remarks: .....

....

Special Bearings Committee
F. D. Egan, Chairman.
Association of Iron and Steel Electrical Engineers,
Empire Bldg., Pittsburgh, Pa.

INDEX TO ADVERTISERS

A

Alliance Machine Company 210
Allis Chalmers Mfg. Company 238
American Gas Association 197

B

Bartlett Hayward Company ..... Cover 1
Benjamin Electric Mfg. Co. 239
Blaw Knox Company 209
E. W. Bliss Company 188
The Bristol Company 190

C

Chapman Stein Company 237
Clark Controller Company 211
Cleveland Crane & Engineering Co. 241
Combustion Engineering Corporation 185–243
Crocker Wheeler Electric Mfg. Company 257
Crouse Hinds Company 195
Cutler Hammer, Inc. 187–201–245

D

DeLaval Steam Turbine Company 223–228
Delta Star Electric Company 224
M. H. Detrick Company 264
Doubleday Hill Electric Company 225
Duquesne Light Company 248

E

Economy Fuse & Mfg. Co. 262
Electric Controller & Mfg. Co. 253
Electrical Engineers Equipment Co. 223
Electric Machinery Mfg. Co. 206
Electric Power Equipment Corp. 263
Electric Service Supplies Co. 231
Electro Dynamic Co. 244
Erie Malleable Iron Company 207

F

Fafnir Bearing Company 242
Farrel-Birmingham Company, Inc. 194
Franklin Electric & Construction Co. 225
Freyn Engineering Company 215–216

G

General Electric Company ..... Cover 4–203–249
Graybar Electric Company 230

H

Harnischfeger Corp. 220
Holophane Company, Inc. 199
Hyatt Roller Bearing Company 252

I

Ideal Commutator Dresser Company 227
International Combustion Engineering Corp. 185–243
International Nickel Company 189
Iron City Electric Company 228
ITE Circuit Breaker Co. ..... Cover 3
Ivanhoe Division of the Miller Co. 236

J

Jefferson Electric Company 212
Jewell Electrical Instrument Company 198
Johns Manville Corp. 259

K

Keystone Lubricating Company 218
A. J. Konkell 260

L

Lapp Insulator Company, Inc. 184

M

Martindale Electric Company 213
Mesta Machine Company 191
Moloney Electric Company 227
Monitor Controller Company 221
Morgan Construction Company 192
Morgan Engineering Company 202
Morganite Brush Company 231
Henry N. Muller Co. 229

N

National Air Filter Company 250
National Carbon Company 219
New Departure Mfg. Company 254
Nichols Lintern Company 214
Norma Hoffmann Bearings Corp. 234

O

Ohio Electric & Controller Company 196

P

B. F. Perkins & Sons, Inc. 233

R

Railway & Industrial Engineering Co. 200
Reed Air Filter Company, Inc. 186
Reliance Electric & Engineering Co. 251
Rockbestos Products Corp. 247
Roller Smith Company 222
Rowan Controller Company 232
Rumsey Electric Company 226

S

Sharples Specialty Company 208
Shepard Niles Crane & Hoist Corp. 235
SKF Industries Inc. 246
Smith & Serrell 224
Stackpole Carbon Company 204
Standard Underground Cable Company 193

T

Thompson Electric Company 232
Timken Roller Bearing Company 261
Tool Steel Gear & Pinion Company 226
Trico Fuse Mfg. Company 240
Trumbull Electric Mfg. Company 258

U

United States Graphite Company 222
R. E. Uptegraff Mfg. Company 229

V

V. V. Fittings Company 256

W

Westinghouse Electric & Mfg. Company ..... Cover 2–233–255
Weston Electrical Instrument Company 230
George D. Whitcomb Co. 205
Edwin L. Wiegand Company 217

MAIN LIBRARY APR 19 1929 ELECTRICAL

On the Mathematical Theory of the Cottrell Electric Precipitator

By A. W. SIMON, Ph.D.*

A number of theoretical derivations, based on Stokes Law and following the method of kinetic theory, of the formula for the cleaning efficiency of a Cottrell pass have already been developed[1,2]. However, from the standpoint of the engineer, I believe the following simple derivation of the formula will be much more satisfactory:

Let us consider the process of electrical precipitation simply from the point of view that it is a reaction between the dust particles on the one hand and the gas ions, or electrically charged gas particles, on the other. Such a reaction would presumably follow the law of mass action familiar in chemistry, that is to say the instantaneous rate at which the reaction proceeds is proportional to the product of the concentrations of the two reacting quantities present at the instant. Put in mathematical form, if we denote by $\frac{dq}{dt}$ the rate of change of the concentration of the dust particles, by q the concentration of the dust particles, and by n the concentration of the ions, we should have:

$$-\frac{dq}{dt} = k\ q\ n \qquad (1)$$

where k is a constant. The negative sign appears because q is decreasing, that is to say its rate of change is negative. Equation (1) however would denote the rate of change as seen by an observer moving along with the gas flowing through the Cottrell pass. With reference to a fixed point, in particular the entrance point, we would have to write:

$$-\frac{dq}{dz}\frac{dz}{dt} = k\ q\ n \qquad (2)$$

where z is the distance traversed. But $\frac{dz}{dt}$ then is simply the velocity V of the gas, and we can therefore rewrite (2) as

$$-\frac{dq}{dz} = \frac{k}{V}\ q\ n \qquad (3)$$

The concentration of the ions we may assume not to vary with z, since they are continually supplied by the discharge electrodes.

The solution of the differential equation (3) is:

$$q/q_0 = 1 - e^{-k\ n\ z/V} \qquad (4)$$

where q_0 is the entering concentration of the dust and e the base of the Napierian system of logarithms.

Replacing the constant product $k\ n$ by α, denoting z by L (the length of pass) and replacing the ratio q/q_0 by y, which is by definition the cleaning efficiency, this formula becomes:

$$y = 1 - e^{-\alpha\ L/V} \qquad (5)$$

which we shall take as our fundamental formula in what follows.

A number of important deductions can be made from the above formula as we shall now proceed to show.

For the purpose of calculations we shall find it convenient to use interchangeably the two forms:

$$y = 1 - e^{-\alpha\ L/V} = 1 - e^{-\alpha\ x} \qquad (6)$$

where we have put x identically equal to L/V.

The significance of the above formula as regards the variation of y with the length of pass L has already been realized by workers[3] in the field of electrical or Cottrell precipitation and needs only brief comment here. The graph of y as a function of L (other factors, in particular the velocity, being constant) is given by Fig. 1, from which it is seen that

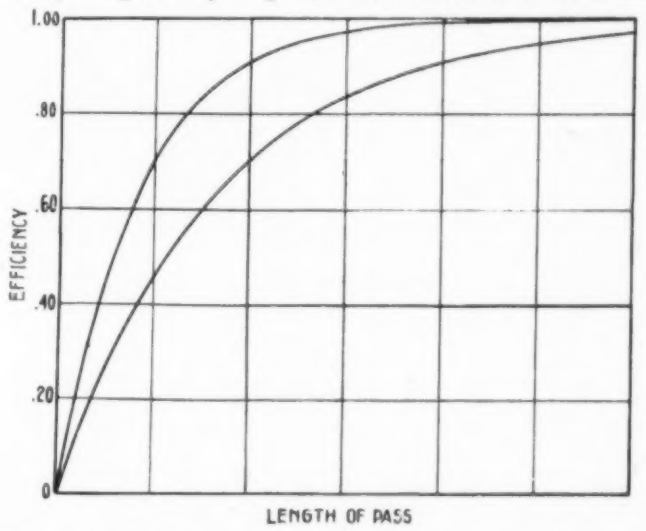


FIG.1—Effect of Length of Pass of Cottrell Precipitator on Cleaning Efficiency. Lower Curve Drawn for Double Velocity of Upper.

the efficiency increases rapidly at first, but increases at a continuously decreasing rate, and finally approaches unity asymptotically.

While, however, the effect of length of pass, i. e. L, on y has been well understood, the effect of the velocity does not seem to have been so well realized. The graph of y as a function of V is given by Fig. 2, from which it is seen that y increases with decreasing velocity, first at a continuously increasing rate and then at a continuously decreasing rate until it finally approaches the value unity asymptotically as V ap-

*Research Physicist, Tennessee Coal, Iron and Railroad Co. (Subsidiary of the United States Steel Corporation), Birmingham, Ala.

proaches zero. The efficiency-velocity curve, unlike the other, has a point of inflection. For the sake of comparison two curves are shown in each of the figures,

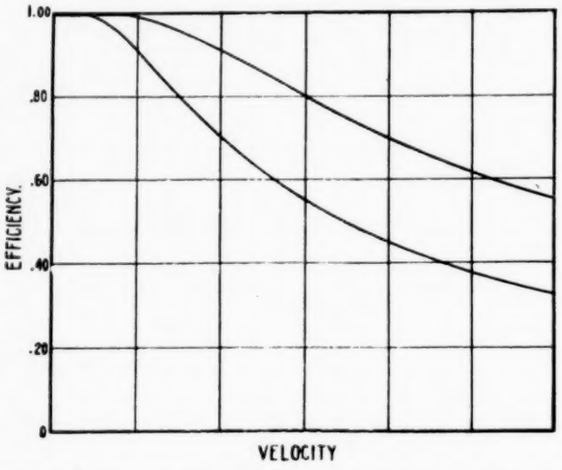


FIG. 2—Effect of Velocity of Gas Through Cottrell Precipitator on Cleaning Efficiency.

the lower curve giving, in the case of Fig. 1, the effect of *doubling* the velocity and in the case of Fig. 2 the effect of *halving* the length of pass.

Formulas (6) contain implicity a very important law, regarding the percentage of the dust precipitated in each pass, which we shall next deduce. Let us suppose that we have a single Cottrell unit consisting

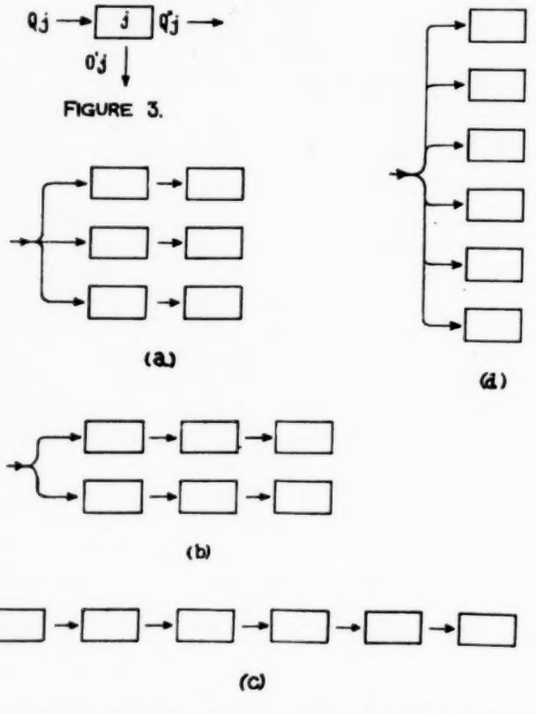


FIGURE 3.

FIG. 4—Four Methods of Connecting Six Cottrell Passes Symmetrically.

of n like passes, each of length l, in series. Consider the j^{th} pass of this series. If we denote by Q_j, Q_j', Q_j'', respectively the quantity of dust entering, precipitated in, and leaving the j^{th} pass (Fig. 3) we have from the definition of y:

$$Q_j'' = Q_1 (1 - y) \tag{7}$$

If now we let f_j represent the fractional part which the dust precipitated in the j^{th} pass is of the dust entering that pass, in other words, if we let f_j be defined by

$$f_j = Q_j'/Q_j \tag{8}$$

then obviously

$$f_j = \frac{Q_{j-1}'' - Q_j''}{Q_{j-1}''} = 1 - \frac{Q_j''}{Q_{j-1}''}$$

Substituting in this last equation for the Q_j'''s their values given by (7), we have further:

$$f_j = 1 - \frac{(1 - y_j)}{(1 - y_{j-1})}$$

and, substituting in turn for the y's their values given by (6), noting also that $L = j\,l$, this becomes:

$$f_j = 1 - \frac{e^{-\alpha l j/V}}{e^{-\alpha l (j-1)/V}} = 1 - e^{-\alpha l/V} = constant_1 \tag{9}$$

Since the right side of (9) does not involve j, we can state that *the fractional part which the dust precipitated in any pass is of the dust entering that pass the same for every pass.*

In other words, if the first pass, of a series of n passes, precipitates 70% of the dust entering it, i. e., the first pass; the *second* pass will precipitate also 70% of the dust entering it; the *third* pass 70% of the dust entering it, and so forth. However, since the first pass removes 70% of the incoming dust, only 30% of the dust entering the first pass is left to enter the second, and 70% of this, or 21% of the total dust entering the first pass is precipitated in the second, leaving 9% to enter the third, where 70% of 9% or 6.3% is precipitated, and so on, according to the table:

Pass	In	Down	Through	y
1	100%	70%	30%	70%
2	30%	21%	9%	91%
3	9%	6.3%	2.7%	97.3%
4	2.7%	1.89%	.81%	98.11%

It is seen that the first two passes take out the major portion of the dust, this means, of course, that successive hoppers can be smaller and smaller, and the final stages require hardly any hopper at all.

An application of the law just deduced gives us an algebraic relation between y and f (Since f_j is the same for all values of j we can now drop the subscript j). This relation is useful for the purpose of computing the resulting efficiency of several passes, provided the efficiency of the single pass is known. We have directly

$$y_1 = f \tag{10}$$
$$y_2 = f + f(1 - f) \tag{11}$$
$$y_3 = f + f(1 - f) + f(1 - f)^2 \tag{12}$$
$$y_n = f + f(1 - f) + \ldots + f(1 - f)^{n-1} \tag{13}$$

Of course, if f for the single pass is known, the efficiency y_n for n such passes in series can also be found from (6), from which we obtain:

$$log\ (1 - y_n)/log\ (1 - f) = n \qquad (14)$$

where the logarithms may be taken to any convenient base, in particular to the base 10. For large values of n it is more convenient to use the last formula than formula (13).

If the efficiency y_2 of two passes in series is known, the efficiency of the single pass can be computed from (11), which yields, solving for f:

$$f = 1 - \sqrt{1 - y_2} \qquad (15)$$

Similar formulas could be derived for calculating, by algebraic methods, the value of f from the observed y of three or more passes, but these formulas would involve successively the solution of cubic, biquadratic, and algebraic equations of higher order, so that here again it would be better to use formula (14), which rewritten becomes

$$log\ (1 - f) = log\ (1 - y_n)/n \qquad (16)$$

where again the logarithms may be taken directly to the base 10.

A second important law regarding the dust transmitted by each pass can be deduced from (6). For this purpose consider the ratio $r_j = Q_j''/Q_j$ i .e. the ratio of the dust leaving the j^{th} pass to that entering it. We have by definition of r_j and from (7),

$$r_j = Q_j''/Q_j = Q_1\ (1 - y_j)/Q_1\ \ (1 - y_{j-1})$$

Substituting for the y's their values in terms of (6) we obtain

$$r_j = e^{\alpha j l/V} / e^{\alpha (j-1)\, l/V} = e^{\alpha\, l/V} = constant_2$$

Since here again the right hand side does not contain j, r_j is the same for every pass, that is to say, *the fractional part of the dust entering any pass, passing (unprecipitated) through that pass, is the same for every pass.* For example, in our case above, the first pass transmits 30% of the dust entering it; the second pass transmits also 30% of the dust entering it, i. e., the second pass, or 30% of 30% or 9% of the dust entering the first pass; the third pass transmits 30% of 9% or 2.7% of the dust entering the first pass, and so on. It will be seen that we might call f the *precipitation factor* and replace it by the symbol p, and r the transmission factor and replace it by the symbol t.

The quantity r or t is particularly useful in computing the cleanliness of the gas after it has passed through n passes in series, provided of course t is known for the single pass. If Q_1 is the concentration of the dust entering the first pass and Q_n'' is the concentration leaving the n^{th} pass, we have from the law just proved above:

$$Q_n'' = Q_1 t^n \qquad (17)$$

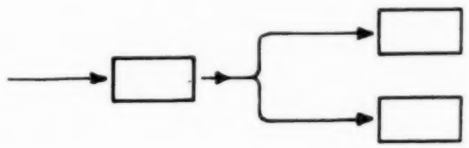
In particular, if gas having a dust concentration of 2.00 grains per cubic foot enters the first pass of a series of three passes for which $t = 30\%$, it will be cleaned down to .054 grains per cubic foot.

It will be seen that the second law just deduced also follows as a consequence from the first, since from the definition of r and f, we have directly

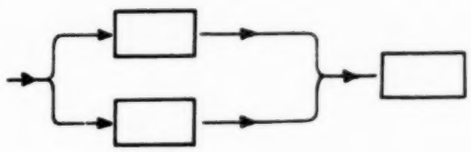
$$r = 1 - f \qquad (18)$$

and, if f is the same for every pass, r also must be the same for every pass.

A third important application of equation (6) is to determine the efficiency of a composite installation from the efficiency of the single pass. In practice, to facilitate repairs, all the gas to be treated is not taken through a single large unit but through several units in parallel, the total gas dividing evenly between these units. Each of the units may in turn consist of several passes in series, as for example in Fig. 4a, where the installation consists of three units in *parallel* and each unit consists of two passes in *series*. Now the problem which presents itself in connection with such composite installations is the following: Suppose we have available a total number N of passes, such that $N = mn$ where m and n are any two integral factors of N, how is the best cleaning obtained, by forming m units in parallel each unit consisting of n passes in series, or n units in parallel, each unit consisting of m passes in series? In particular if we have six passes at our disposal, since $6 = 3{\cdot}2 = 2{\cdot}3 = 1{\cdot}6 = 6{\cdot}1$, is the best cleaning obtained by connecting the single passes as in Fig. 4a, or Fig. 4b, or Fig. 4c, or Fig. 4d?



(a)



(b)

FIGURE 5.

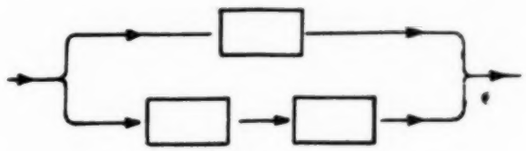


FIG. 5.

Let us suppose in what follows that the total gas volume to be treated per unit time is v, supposed always the same, and let the length of the single pass be denoted as before by l. Consider the case of m

units in parallel where each unit consists of n passes in series. We have then the velocity V through each unit proportional to v/m and the length L of each unit equal to nl, so that x of our formula (6) which is equal to L/V is proportional to $mnl/v = Nl/v$. Consider next the case of n units in parallel where each unit consists of m passes in series. For this case we have V proportional to v/n and L equal to ml, so that finally x is proportional to $nml/v = Nl/v$ exactly as before. Therefore if we denote an installation of this type as a composite symmetrical installation, we can state *that the resulting cleaning efficiency of a composite symmetrical installation depends only on the total number of passes in the installation and not on their manner of connection.*

With regard to the special cases illustrated schematically in Fig. 4 we can therefore say that all four schemes would give the same cleaning efficiency. The manner of connection then would be determined by other considerations, chief of which perhaps is that if one unit is off gas for repairs the arrangement of Fig. 4d would give the highest cleaning efficiency, since if one of the units of Fig. 4d is off gas, x is proportional to $5l/v$ while, under similar conditions for the scheme of Fig. 4a, x would be equal to $4l/v$ and for the scheme of Fig. 4b, x would be equal to $3l/v$. In general for one unit off gas the cleaning efficiency of a symmetrical installation of m units in parallel would be changed in the ratio

$$log\ (1 - y_{m-1})/log\ (1 - y_m) = m/(m - 1) \quad (19$$

In general it is seen that the change in efficiency is smallest when m is largest, that is the greater the number of units connected in parallel.

If the efficiency of the arrangements of Fig. 4 is 91%, the efficiency is changed, if one unit is taken off gas for each of the four schemes, from 91% to 79.9%, 70.0% 0%, and 86.6%, for the schemes 4a, 4b, 4c, 4d, respectively. This excludes the scheme of 4c from practical consideration, while lack of economy of space and perhaps difficulty in getting even distribution might bar also the scheme of 4d, leaving us to choose between 4a and 4b, and of these 4a would be best from the point of view of highest resulting efficiency provided one unit is off gas for repairs.

So far we have dealt only with what we have termed a symmetrical scheme of connection. We might, however, also ask whether there is any advantage, as regards cleaning efficiency, if we connect units as in Fig. 5a and Fig. 5b, in each of which we have used a total of three passes. Let us suppose that the efficiency of the first pass of Fig. 5a is 70%, and therefore that of the second 91%. From the definition of the efficiency y we have directly:

$$y_2 = f_1 + f_2\ (1 - f_1) \qquad (20)$$

whence we have as the resulting efficiency y of the arrangement of Fig. 5a:

$$y = .70 + .91\ (.30) = 97.3\%$$

and for that of Fig. 5b:

$$y = .91 + .70\ (.09) = 97.3\%$$

while for three passes connected directly in series we would have, putting $f = .70$ in formula (12), for the efficiency:

$$y = .70 + .70\ (.30) + .70\ (.30)^2 = 97.3\%$$

as before. In other words here again the cleaning efficiency does not depend on the manner of connection of the single passes.

There is, however, one other scheme of arranging three units, namely that represented by Fig. 6, and it is interesting to determine whether this scheme also gives the same cleaning efficiency as those of Fig. 5. If the efficiency of the first pass of Fig. 5a is 70%, the efficiency per pass of the scheme of Fig. 6 would be 91% (due to the fact that the velocity for the same total volume treated per unit time is halved in the latter case), so that the gas passing through the single pass is relieved of 91% of its dust while that passing through the double pass is relieved of 99.19%, and the combined efficiency of the installation is therefore 95.09%, in other words with this scheme there is a distinct *loss* in efficiency over those of Fig. 5.

In the preceding we have usually assumed that α and l were the same for each of the passes. When this not the case but the precipitation factor f_j of the j^{th} pass of n passes in series is given by

$$f_j = 1 - e^{-\alpha_j\ l_j/V_j}$$

we have

$$Q_j'' = Q_j\ e^{-\alpha_j\ l_j/V_j} = Q_{j-1}''\ e^{-\alpha_j\ l_j/V_j}$$

Since

$$\Sigma\ Q_j' = Q_1 - Q_n''$$

and

$$y = (Q_1 - \Sigma\ Q_j)/Q_1$$

we have, finally

$$y = 1 - e^{-\left(\frac{\alpha_1\ l_1}{V_1} + \frac{\alpha_2\ l_2}{V_2} + \ldots + \frac{\alpha_n\ l_n}{V_n}\right)} \qquad (21)$$

or

$$log\ (1 - y) = \sum_{j=1}^{j=n} \alpha_j\ l_j/V_j = \sum_{j=1}^{j=n} log\ (1 - f_j) \quad (22)$$

In conclusion I would like to point out with regard to the range of validity of Eq. (6) and the efficiency-velocity curve as drawn in Fig. 2, that equation and curve are very likely correct only as long as the critical velocity of turbulence is not exceeded. Very likely the curve would not hold for relatively high velocities, but would drop rather more rapidly than the curve indicates after the point of turbulence had been passed.

In conclusion I wish to thank Mr. G. G. Crawford for the inspiration and encouragement he has given me in this work, and also Mr. J. E. Fries for his kind criticism of this paper.

1 Deutsch, Ann. Phys. **68**, 335, (1922)
2 Strong, Ann. Phys. **48**, 251, 1915)
3 Deutsch, Zt. f. Tech. Phys., **6**, p. 433, (1925)

*Starting Characteristics of Steel Mill Synchronous Motors**

By H. H. ANGEL†

FOR a number of years the wound rotor induction motor has been used on practically all steel mill constant speed main roll drives. This motor is admirably suited for such service due to its ability to produce high starting torques and carry sustained overloads, which are requirements in steel mill service. However, inherent with the best motors of this type, is its low power factor, which penalizes the generating and distribution system with wattless current.

Synchronous motors have been used on air compressors, motor generator sets, and other applications where the starting duty does not require more than twenty to thirty percent of full load starting torque .

On low speed applications the first cost is somewhat less than its wound rotor induction motor competitor and its efficiency is slightly higher.

In the last three years improvements in automatic starting equipment and in the designs of synchronous motors whereby more starting torque with a minimum current input is available have resulted in a number of installations.

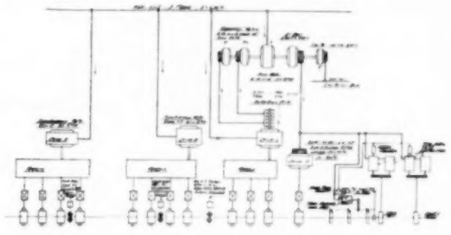


FIG. 1—Arrangement of Electric Drives for 27", 24" and 21" Semi-Continuous Skelp Mill.

Figure 1 shows the layout of the electric drives in the 27"-24"-21" semi-continuous sheet bar and skelp mill in the Maryland Plant of the Bethlehem Steel Company.

The first four stand unit shown on the left, known as Drive "A", is driven by a 4000 HP, 83.3

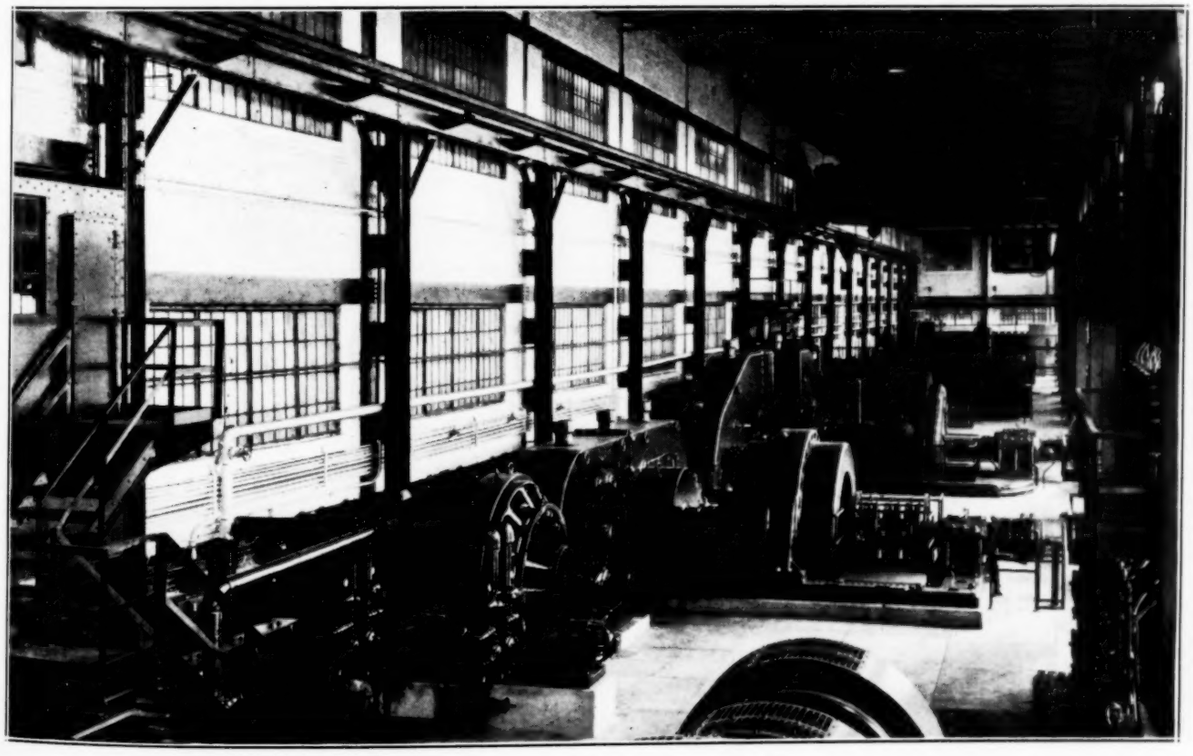


FIG. 2—General view of the motor rom of the 27"-24"-21" continuous skelp and sheet bar mill of the Bethlehem Steel Co., Sparrows Point, Md.

*Presented before Philadelphia District Section, A. I. & S. E. E., November 3, 1928.

†Motor Control Spec., Bethlehem Steel Co., Sparrows Point, Md.

RPM, 25 cycle, 6600 volt synchronous motor. The next unit to the right is Drive "B", whose four stands are driven by a 6500 HP, 187.5 RPM, 25 cycle, 6600 volt synchronous motor, the field excitation for both motors being supplied from a 250 volt exciter on the motor generator set for controlling other drives in the mill.

Figure 2 is a picture of the motor room in which these motors are located.

TABULATION OF EFFICIENCY OF CONSTANT SPEED MAIN ROLL MOTORS

Efficiency & Power Factor	4000 H.P. 83.3 R.P.M.		6500 H.P. 187.5 R.P.M.	
	Synchronous 80% P.F.	Induction	Synchronous 80% P.F.	Induction
. Eff. ½ Load	91.6	90.2	90.8	90.0
" ¾ "	93.3	91.8	95.0	93.5
" Full "	94.0	92.5	95.7	94.5
P. F. ½ "		.62		75.0
" ¾ "		.75		82.0
" Full "		.82		85.0

FIG. 3.

Figure 3 is a tabulation of the efficiencies of the above synchronous motors at 80 percent leading power factor and also efficiencies and power factors of induction motors wihch would have been suitable for these applications.

Figure 4 shows the elementary diagram of the starting equipment for both motors. The Korndorffer method of two step closed circuit transition is provided. When the main master switch is in

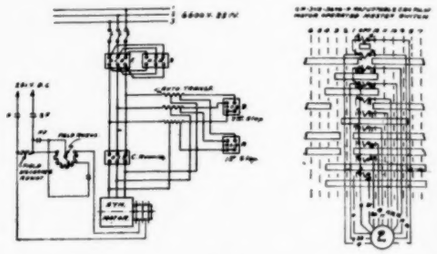


FIG. 4—Elementary Layout of Starting Equipment for 4000 hp. and 6500 hp. Synchronous Motors.

the "off" position oil switch "A" is closed, completing the "Y" point on the auto-transformer and

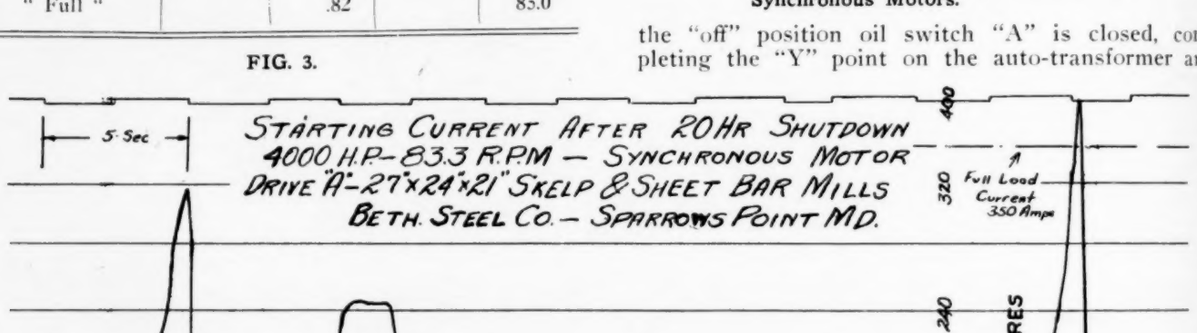


FIG. 5

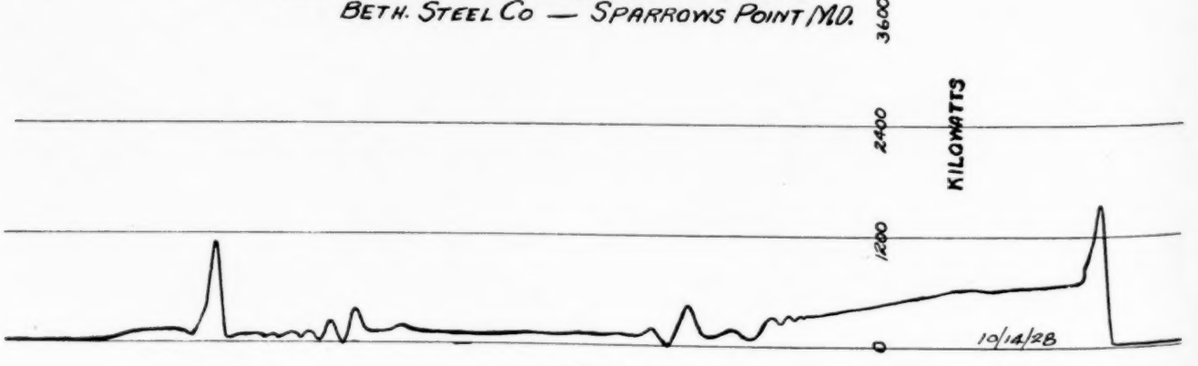


FIG. 6.

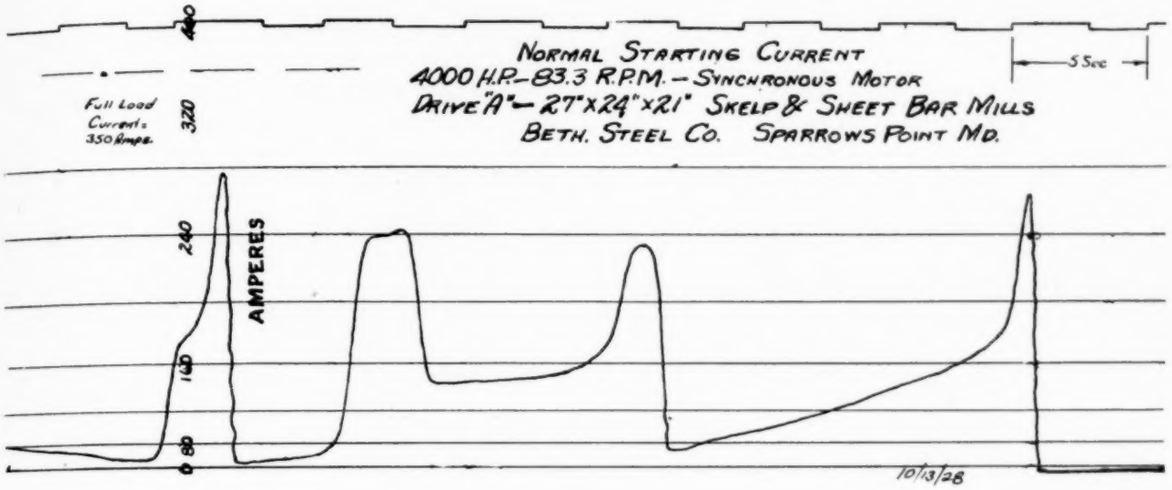


FIG. 7.

providing a 320% starting tap. Moving the master controller to the forward direction closes line oil switch "F" which immediately starts the motor on low voltage, the synchronous field being short circuited through a discharge resistor. At the same time oil switch "F" is closed, the motor operated cam master switch, which provides the sequence of operations, starts to operate. After a time interval of approximately thirteen seconds the master has travelled to step 2, tripping out oil switch "A" and closing "B". During the short interval of time during which both oil switches are open the motor is on the line in series with the reactance of the auto-transformer. The closing of second step "B" provides a 70% voltage tap and the motor continues to increase in speed.

After the motor attains approximately 95% synchronous speed, the voltage and frequency of a single phase alternating current generator geared to the motor becomes high enough to operate a differential frequency relay. As the motor operated master switch reaches point 4 the circuit is completed to the weak field excitation contactors "1F" and "2F" which will close if the differential frequency relay has functioned. If the motor has not come up to this speed, the master switch will cease operating and in a definite time, a program relay, which is connected up to trip the starting oil switch if the motor does not get across the line in the time the master controller provides, will trip out the forward oil switch. If the motor does attain 95% speed and weak field is applied through the closing of contactors "1F" and "2F", the master will reach point 5 when oil switch "B" will be tripped and "C" closed, the motor again being in series with the reactance of the auto-transformer during the short interval both oil switches are open. The closing of "C" oil switch places the motor across full voltage and also closes contactor "FF" which cuts out the resistor in series with the field. The motor operated master continues to operate until it cuts out on point 9.

When shutting down, the main master controller is brought to the "off" position, tripping out the forward oil switch and continuing the operation of the master controller from point 9 to point 13 which is the "off" position. In the off position "C" breaker is tripped out and "A" closes.

If it is desired to operate the motor in the reverse direction, the operation of the main master

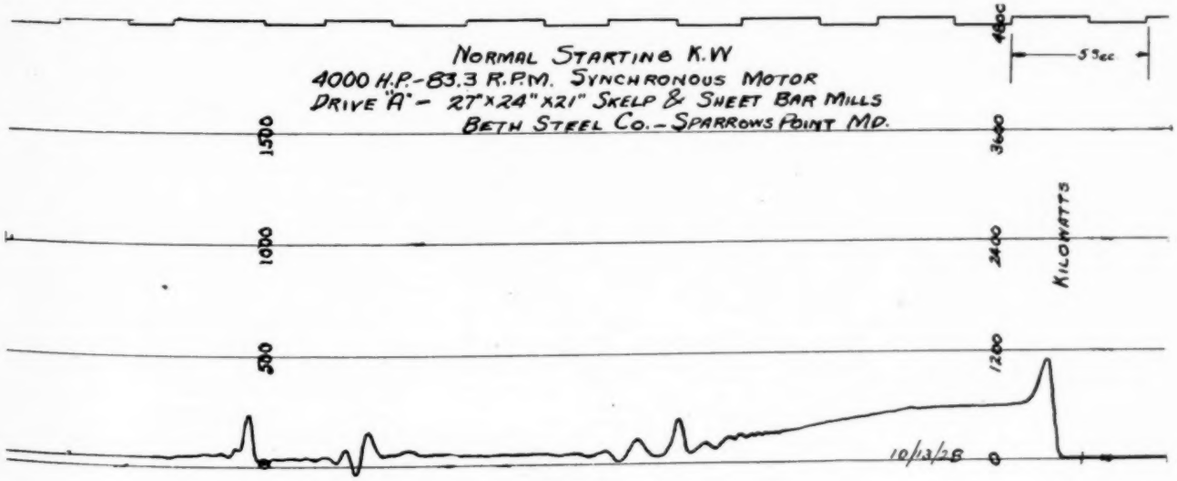


FIG. 8.

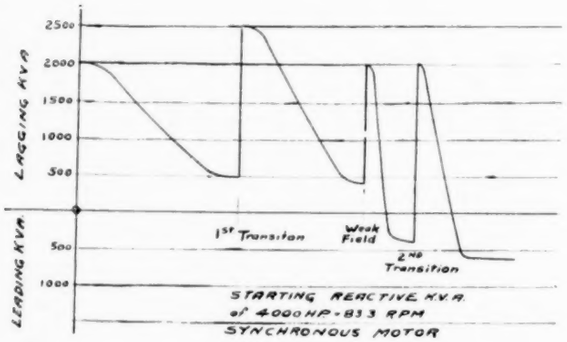


FIG. 9—Starting Reactive k.v.a.. of 4000 hp., 83.3 rpm., Synchrouous Motor.

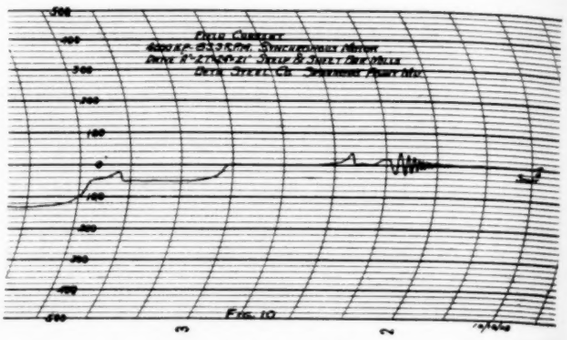


FIG. 10.

closes "R" oil switch which starts the motor in the same sequence as before.

On this equipment mechanical interlocks are installed between the forward and reverse oil switches. These are also electrically interlocked to oil switches "A", "B", and "C" to prevent starting on the second step or on full voltage. The switchboard panel is also provided with overload, no-voltage, and field excitation protection. There is also a definite time interval for emergency plugging since the reverse oil switch cannot close until the motor operated master switch has travelled from point 9 to the off position.

Figures 5 and 6 show the starting currents and power respectively on the 4000 HP Drive "A" synchronous motor starting the mill at a room temperature of 65 deg. F. after a 20 hour shut down. Both charts were operated by one motor which gave a paper speed of 12" per minute. This starting peak of 400 amperes, or 115% of full load current is much higher than normal which will be shown later. The second peak is obtained when the motor receives 70% voltage, the third when weak field is applied, and the fourth when the motor receives full voltage. The transition peaks are well below full load current and the starting power is low due to the poor starting power factor of the motor.

Figures 7 and 8 show the starting current and power during normal operating conditions. All peaks are much below full load current.

Figure 9 shows the starting reactive KVA values on the 4000 HP motor.

Instantaneous values were observed and the curves were drawn from observations of the relative rate of increase and decrease.

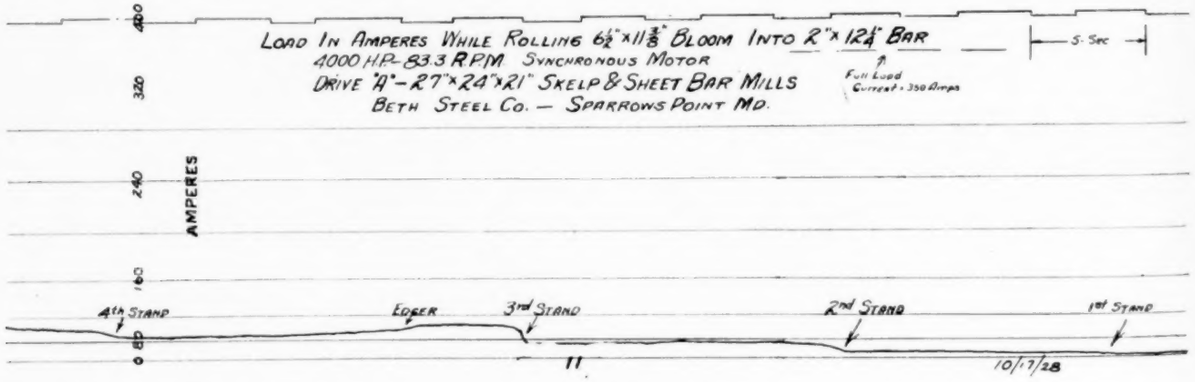


FIG. 11.

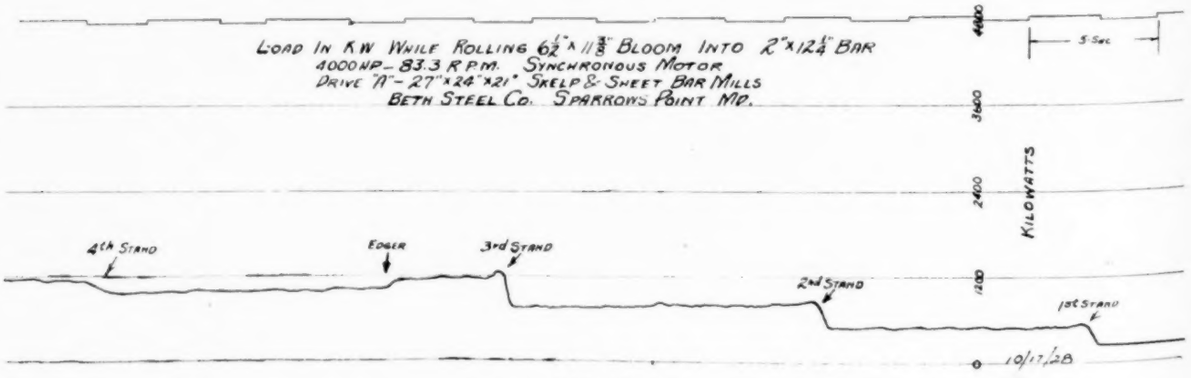


FIG. 12.

Figure 10 shows the field current of the 4000 HP motor. The induced voltage with its change of frequency can readily be noted.

Figures 11 and 12 show the current and power respectively while rolling a 6"x11⅜"x20' bloom into a 2"x12¼" bar. It can be seen this drive is very lightly loaded while rolling this section.

Figure 13 shows a section of the chart from the graphic meter on Drive "A" panel while rolling the above mentioned section, each peak representing one bloom passing through the mill.

Figures 14 and 15 show the normal starting current and power on the 6500 HP synchronous motor on Drive "B". All current peaks are well under full load.

Figure 16 shows the starting reactive KVA value on the same motor. Instantaneous values were observed and the curves were drawn from observations on the relative rate of increase and decrease.

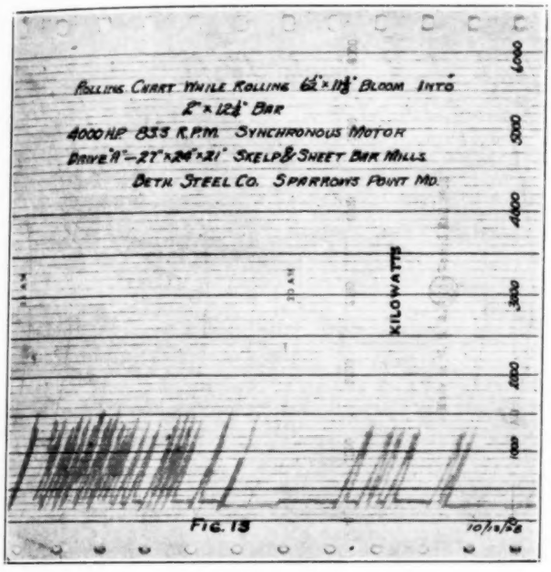


FIG. 13.

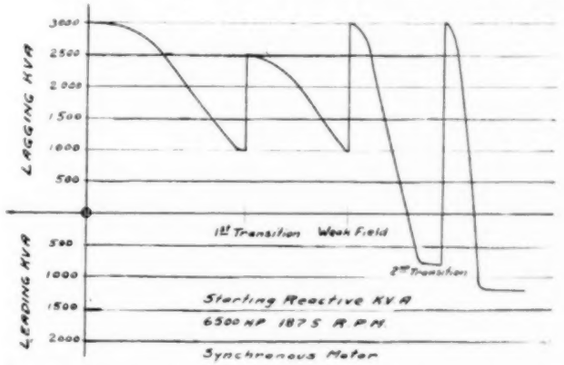


FIG. 16—Starting Reactive K.V.A., 6500 H.P., 187.5 R.P.M., Synchronous Motor.

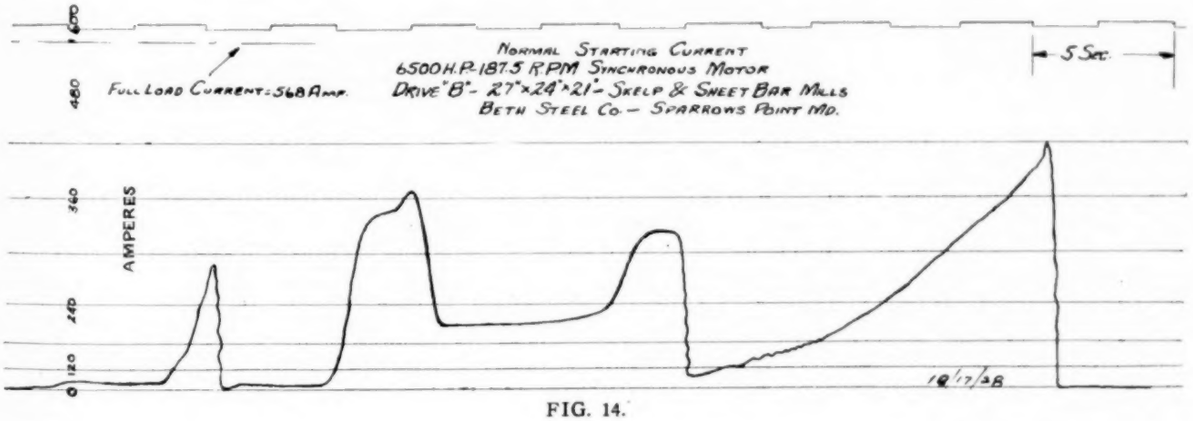


FIG. 14.

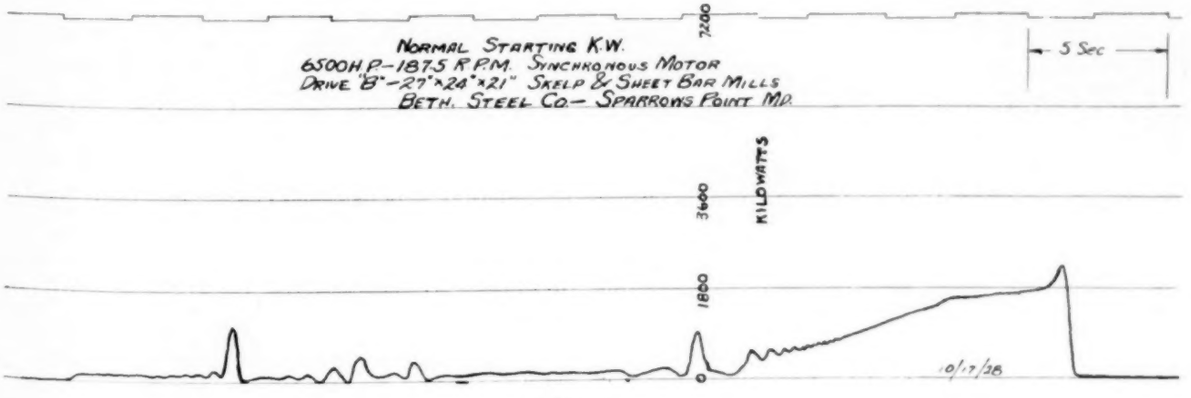


FIG. 15.

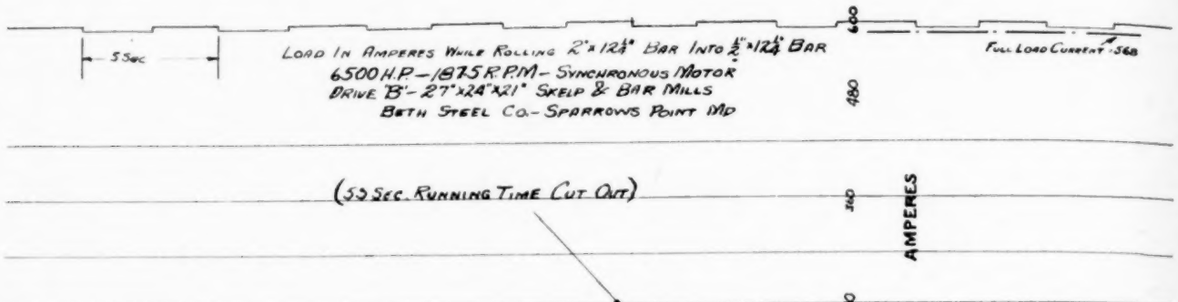

5 Sec
Load In Amperes While Rolling 2"x12¾" Bar Into ½"x12¼" Bar
6500 H.P. – 187.5 R.P.M. – Synchronous Motor
Drive "B" – 27"x24"x21" Skelp & Bar Mills
Beth. Steel Co. – Sparrows Point Md.
Full Load Current - 568
(55 Sec. Running Time Cut Out)
AMPERES
600
480
240
0
10/17/28

FIG. 17.

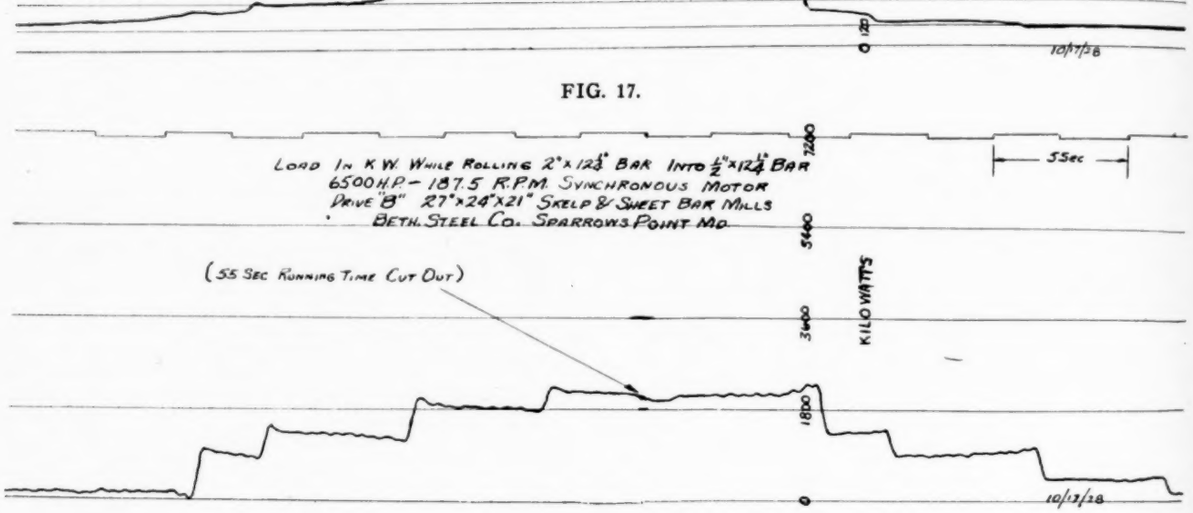

Load In K.W. While Rolling 2"x12¾" Bar Into ½"x12¼" Bar
6500 H.P. – 187.5 R.P.M. Synchronous Motor
Drive "B" 27"x24"x21" Skelp & Sheet Bar Mills
Beth. Steel Co. Sparrows Point Md.
5 Sec
(55 Sec Running Time Cut Out)
KILOWATTS
3600
1800
0
10/17/28

FIG. 18.

Figures 17 and 18 show the current and power respectively while rolling 2"x12¼" bar into a ½" x 12¼" bar.

Figure 19 shows a section of the chart from the graphic meter on Drive "B" panel while rolling the above mentioned section, each peak representing one bar passing through the mill.

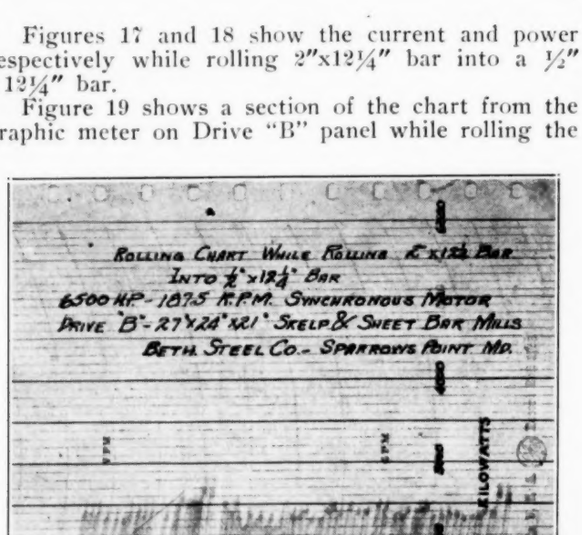

Rolling Chart While Rolling 2"x12¾" Bar
Into ½"x12¼" Bar
6500 H.P. – 187.5 R.P.M. Synchronous Motor
Drive "B" – 27"x24"x21" Skelp & Sheet Bar Mills
Beth. Steel Co. – Sparrows Point Md.
KILOWATTS
Fig. 19

FIG. 19.

This equipment has been in service since June, 1927, and has given very satisfactory service. The plant power factor has been increased from 5 to 10 percent and the elimination of the wattless current taken by large induction motors in adjacent mills has raised the voltage on the system.

Discussion

L. A. Umansky*: It certainly is quite befitting that the first paper dealing with operating data on larger rolling mill synchronous motors was presented by one of the Sparrows Point engineers. You undoubtedly recall the tests made at the same steel plant by F. O. Schnure in the Spring of 1925 for the purpose of determining experimentally the torque required to start from rest a continuous mill and to specify, on an intelligent basis, the starting characteristics of the driving synchronous motor. We should consider these tests, described in the A. I. & S. E. E. Proceedings for 1925, as laying the corner stone of this latest development in the rolling mill drives.

And now, only three years later, we are fortunate of having heard this excellent presentation

*Industrial Engr. Dept., General Electric Company, Schenectady, N. Y.

by Mr. Angel, telling us about their experience with these motors already built and installed.

I want to take this opportunity and will attempt to clarify to a certain extent the few basic characteristics of such synchronous motors as are apt to be used for driving rolling mills. The electrical manufacturers are often asked: Can you build a synchronous motor to give us a sufficiently high starting torque? 50%, 75%, 100% or 150% normal torque are specified, as the case may be.

With the exception of very low speed 60 cycle motors there is no trick involved in building such a motor, if no limit is set on the line current or KVA to correspond to the specified starting torque. It is the ratio of the starting torque (expressed in percent of normal or rated torque) to the starting line KVA (also expressed in percent of normal) that best describes the starting characteristic of a synchronous motor. I suggest that we think more and more in terms of this ratio, for which a name of **"torque efficiency"** seems to be well adapted. For instance, the 4000 h.p.-83.3 r.p.m. motor, mentioned by Mr. Angel, has shown on test to have a starting torque of 173% normal, starting KVA of 399% normal, and it has, therefore, a torque efficiency of 43%. The 6500 h.p.-187.5 r.p.m. motor has a still higher torque efficiency of 56%.

Now the mill driven by the 4000 h.p. motor does not require anywhere nearly as much as 173% starting torque; nor is a 399% starting current particularly desirable for any power system. Hence a logical answer: This drive may and should be started at reduced voltage.

A starting auto-transformer is used for this purpose. How does the selection of a starting tap affect the torque, line current and torque efficiency?

Let us remember that a synchronous motor, when being started, is nothing but a squirrel cage induction motor; hence the general rule holds true: the available torque varies as a second power of applied voltage. For instance, the above motor, when started on 40% voltage, will develop 16% of that torque value which is available at full voltage, i. e. 16% of 173%, or 27.5% normal.

The current drawn by the motor varies directly with the applied voltage; in other words, at 40% voltage the motor windings will carry 40% of 399%, or 160% normal amperes. The line current is, of course, smaller due to the transformer action of the auto-transformer; with a 40% tap used the line current is only 40% of the current that flows at the same time through the motor winding. In other words, in this case the line current is only 40% of 40%, i. e. 16% of the current inrush that would be with full voltage starting; in other words, the line KVA will be 64% normal. Thus the line current also varies as the second power of the voltage applied to the motor.

We may make, therefore, a general statement: If an auto-transformer is used for starting a motor, then the starting torque and the line current both vary in the same proportion. The "torque efficiency" remains constant.

With these elementary facts firmly established in our minds, we may more readily analyze the motor performance. Suppose that you need a torque of not more than 50% normal to start the mill from rest and that you have a choice between two motors:

	Starting Torque at Full Voltage	Starting KVA at Full Voltage
Motor A	120% normal	450% normal
Motor B	75% normal	250% normal

Which is a better motor to choose? To get a 50% starting torque the motor A will be started on $100 \times \sqrt{\frac{50}{120}} = 100 \times \sqrt{.416} = 64\%$ tap and the line KVA will be 187% normal. The motor B, to get the same torque, will be started on $100 \times \sqrt{\frac{50}{75}} = 83\%$ tap and the line KVA will be 167% normal. Thus, the motor B is a better one to select in this hypothetical case, because it gives a lower line KVA for the same starting torque, or a higher torque for a given line KVA. The same result could be deducted at once by comparing the torque efficiencies of either motor: for the motor A it is $\frac{120}{450} = 26.7\%$, and for the motor B it is $\frac{75}{250} = 30\%$.

Only if we think that we may need, once in a while, a higher value of starting torque than 50%—say 100%—we may decide in favor of Motor A. This motor, if thrown directly on the line, will give us a torque of 120%, while the motor B will be limited to 75% normal.

We see, therefore, that the starting torque, inherent to the motor itself (i. e. at full voltage) should not necessarily be the deciding factor in motor selection. The 25 cycle motors in general and the 60 cycle motors of moderate and high speed, usually have a full voltage starting torque of higher value than may be needed to start almost any mill. Only the low speed, high reactance, 60 cycle motors may be limited in their starting torque, even at full voltage, and only then the question "for how high a starting torque can this motor be built"—may be justified. Otherwise, an analysis of the "torque efficiency" should be more illuminating.

Reactor type starters are often discussed as against auto-transformers. There is no doubt in my mind that as far as simplicity and reliability are concerned nothing can excel a reactor. But its fundamental limitation is evident: when a motor is connected to the line through a reactor, its torque is again reduced as the second power of applied voltage, while the line current in this case equals the motor current and is reduced only as the first power of applied voltage. In other words, the reactor spoils the torque efficiency inherent to the motor, while the auto-transformer maintains it.

In several late cases, a "combination" starting equipment has been applied by the General Electric Company for starting very large mill type synchronous motors: The motor is started on low voltage tap of an auto-transformer and, after a certain speed is reached, it is connected to the line through a reactor; then, when the motor is practically in synchronism, the reactor is short circuited. Thus the high torque efficiency at starting is combined with smooth transfer to the full voltage line. This method gives a truly "painless starting" even with the largest units and limited power systems.

If the power system is sufficiently large, then an "across-the-line" starting may be well considered. For a given system and given horsepower of the drive the lower is the motor speed and the higher

is the frequency, the more feasible becomes this type of starting. Motors themselves can be readily built to stand the starting current inrush, and the control equipment is certainly greatly simplified.

We are usually laying more stress on the starting torque and torque efficiency than on the value of pull-in torque, i. e., on the ability of the motor to pull in step after reaching 95% synchronous speed. Mill friction is the load that has to be overcome by the motor when starting; the static friction existing at the break-away point is considerably higher than the running friction when lubrication is beginning to take effect. Thus, the pull-in torque of a rolling mill motor may be lower than the starting torque, everything else remaining constant. If, in an exceptional case, a synchronous motor may be required to start or back out with metal in the rolls, in order to clear a cobble, it is not conceivable that it will be required to pull-in step under these conditions.

It may be safely stated, gentlemen, that the use of synchronous motors for driving rolling mills has certainly passed the experimental stage. This motor has come into its own. The only danger to it lies in misapplication, in not fitting a proper motor to a given job.

In finishing, I wish to point out another place in steel mills where the use of synchronous motors will be soon extended. This will repeat the statement which I have already made on other occasions. As our power systems grow, the need of flywheel-equipped motor generator sets for reversing drives will diminish; once flywheels will be eliminated, synchronous motors will be substituted for slip ring induction motors. First cost and maintenance of reversing drives will be reduced and efficiency increased.

Several such equipments, of moderate size, are already installed. Maybe in another five or ten years we will see, say, large blooming mills equipped in a similar manner.

K. M. Raynor*: One thing which has already been mentioned and which is very noticeable in the slides shown by Mr. Angel, is in relation to the value of the starting current taken by the motor on application of the field as compared to the starting current taken on application of full voltage in the case of the 4000 h.p. motor. This value I noticed reached approximately the current taken on the first point of starting, while in the 6500 h.p. I noticed it was somewhat lower. I assume that the starting conditions and the application of the voltage are the same, and was just wondering why this difference in current at that particular point of starting.

H. H. Angel: The only thing I can see that enters into that is the adjustment on the fingers of the master controller which changes the timing. The second factor would be the strength of the field which was applied to the motor.

F. O. Schnure†: I do not think I have very much to add to what has already been said, except to point out the economic features in the installation. Primarily there is a 5% to 10% saving in first cost, which in this particular case ran to probably $8,000 or $10,000, and the increase in efficiency on a mill like this rolling large tonnages is apt to be of considerable importance. At the end of the year I have roughly estimated that we may expect from $50 to $100 a month in power saving on a synchronous motor over the induction on these two types of motors. That is a feature that should not be overlooked.

R. M. Fuller*: One thing I did not gather from Mr. Angel's paper, that is simply an operating detail. Did I understand him to say the master controller is manually operated, or automatic by using a button?

H. H. Angel: You have an ordinary hand operated master controller located in the operating pulpit. When the operator places the master in the direction desired, the resultant operation is entirely automatic.

W. H. Feldmann‡: I should like to add my word of appreciation to Mr. Angel for his paper. Papers that deal with such specific test and operating information contain a great deal of real information, far beyond what we usually find in theoretical discussions.

We had an amusing experience about four years ago in conjunction with the application of synchronous motors on single stand copper and brass rolling mill drives. The Copper Company was, at that time, very doubtful about the suitability of a synchronous motor for the drive, and it was only after a guarantee was given that they were willing to use it. They were afraid the synchronous motor would immediately pull out of step when the billet entered the rolls. It was the practice of the operators of the mill to gauge the amount of reduction that was possible by slowing down the induction motors they had used previously. They attempted, with the synchronous motor driven roll, to take a bigger and bigger bite, with the result that three safety bars and one of the rolls were broken, before they learned synchronous motors do not slow down with load. The synchronous motors did not pull out of step.

I think Mr. Umansky's admonition relative to the proper application of synchronous motors is very important. Certainly the synchronous motor has splendid characteristics on applications for which it is suited, but it takes capable engineering to make the proper application.

H. K. Hardcastle†: I just want to congratulate Mr. Angel on his graphic curves, showing what is going on in the field and stator winding during the starting period of a synchronous motor. This information is most valuable. Definite synchronized information is sometimes pretty hard to get under actual operating conditions.

I might point out that judging from the curves there is apparently no reason why you could not start these motors faster than you do. Thirty-five seconds could be cut down to possibly 15 or 20 seconds, by the use of current limit acceleration without exceeding the peaks shown on the curves.

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This might also make it possible to eliminate one step of acceleration and provide a simpler controller.

I might also say a word about the growing use of synchronous motors. Of course, we are not motor builders but we find the applications for synchronous motors multiplying where formerly they would not have been considered. This has been brought about by the recent improvements in the synchronous motor design and, in the new simplified automatic self-contained controllers, which are now available.

A good many installations have gone in recently on pumps. I saw one a short time ago where it was desirable to keep up the torque of the synchronous motor during acceleration on account of the load on the centrifugal pump increasing rapidly with the speed. In this particular case the controller used on auto-transformer 50% line volts for the first step, and then slid over to a reactor giving 72% line volts. As the motor speed increased the current from the line decreased and the effect of the reactor was proportionately reduced, thus automatically increasing the voltage at the motor terminals, so that it was approximately 85% line volts, when the transition was made to full voltage without opening the circuit.

There is one other point. I noticed Mr. Angel spoke of bringing on the field in two steps, and we can all see the advantage of not bringing the field on too rapidly. On this same job, which I just spoke of, involving a 500 HP. 2200 volt, 3600 RPM synchronous motor, we built the controller to bring on the field in two steps. As an experiment, however, we cut out the first step of the field and brought the field on at full voltage while the primary was connected to the reactor. With this arrangement, the motor seemed to pull in just as nicely with one step field excitation, as with two. This was due possibly to the time lag caused by the reactance of the Turbo type of field winding, used on this particular motor, but it is interesting as it showed another way in which the control could be simplified.

W. B. Shirk*: I wish to compliment Mr. Angel on the presentation of his paper and I am sure it has been a great deal of pleasure to all those present to listen to a paper which has been prepared by a steel mill operator who has in operation at his plant two very large main roll drive synchronous motors.

In order that I may add something of value to this meeting and which will also prove of assistance to you gentlemen in selecting the motor which has the most desirable starting characteristic, I would like to start with the fundamental facts which determine the size of the motor for a particular application, so that I may bring out clearly the factors which influence the starting characteristics of a synchronous motor.

Knowing the size of the mill, the number of stands the motor will drive, the work to be done in each pass and the tonnage to be rolled we are able to calculate the R.M.S. or HP. rating of the motor and also the peak loads the motor will be required to carry during the normal process of rolling. The R.M.S. rating and also the "pull-out-torque" of the motor are the two most important factors which influence the frame size upon which the motor will be built.

In order that I may be clearly understood, I wish to point out at this time that my remarks which are to follow are all based on 100% voltage applied at the motor terminals.

Suppose it is decided to use a motor with a "pull-out-torque" of 300% times normal full load torque. Since the pull out torque is one of the factors which influences the motor frame size it is possible that the frame size required to develop 300% pull out torque is slightly over-size when you considered that the same R.M.S. rating and a pull out torque of 200%. With an over-size frame it is therefore possible to obtain higher starting torques than it is with a frame which is very closely rated due to the fact that larger frames will take more KVA from the line than the smaller frame which means the larger frame will develop a higher starting torque if the torque efficiency of the two frames are approximately the same.

Synchronous motors built approximately ten years ago had a torque efficiency (torque per KVA) of approximately 20%. As the design engineer became skilled in the art of designing synchronous motors the torque efficiency has been gradually increased until at the present time for machines ranging from 4 to 30 poles, a "pull-out-torque" of 250% and a "pull-in-torque" of 40% or less we are able to obtain a torque efficiency of 40%. It is therefore quite interesting to note that the torque efficiency has been double in the last ten years.

The "pull-in-torque" of a synchronous motor is another important factor which must be considered when selecting the starting characteristics for drive. The inherent characteristics of a synchronous motor are such that you cannot obtain simultaneously from a given frame both the maximum "starting-torque" and the maximum "pull-in-torque." If you require the maximum starting-torque the machine can develop it is not possible under such conditions to obtain the maximum "pull-in-torque." If you require the maximum "pull-in-torque" the machine can develop you cannot obtain the maximum starting torque. For a given application it is therefore necessary that the starting conditions be analyzed very carefully so that a compromise can be made between the "starting" and "pull-in-torques" in order to obtain the most desirable performance from the machine selected.

After considering the starting characteristics of synchronous motors it might be well to say a few words relating to the "starting" or "damper bar" winding used in this particular class of equipment. The damper bar winding in a synchronous motor is designed primarily for starting duty only, whereas the same type of winding which is used in the ordinary squirrel cage induction motor is designed for continuous operation. It is therefore necessary to study the construction of the damper bar winding used in synchronous motors very carefully so that the maximum reliability can be obtained. We have observed from test data, that the total heat generated in the damper bar winding during the starting period, that it is very desirable to dissipate practically all of the heat into the pole iron. It therefore very important that the amount of starting winding external to the pole iron be reduced

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to a minimum due to the fact that the majority of failures that have occurred due to overheating of the damper winding. have occurred in that part of the winding which is exposed to the air and external the pole iron.

It is of particular interest to both operating engineers and central station companies when applying synchronous motors that the starting KVA and also synchronizing KVA be kept to a minimum. There are three general types of starting schemes in use today namely, full voltage, reactor and auto-transformer for starting larger main roll drive synchronous motors. Mr. Angel has explained one type of auto-transformer scheme which uses a starting auto-transformer having two "Y" points in order to obtain two step starting and closed transition. There is also another auto-transformer scheme Fig. 1 which is in use at the present time and which has several very desirable characteristics.

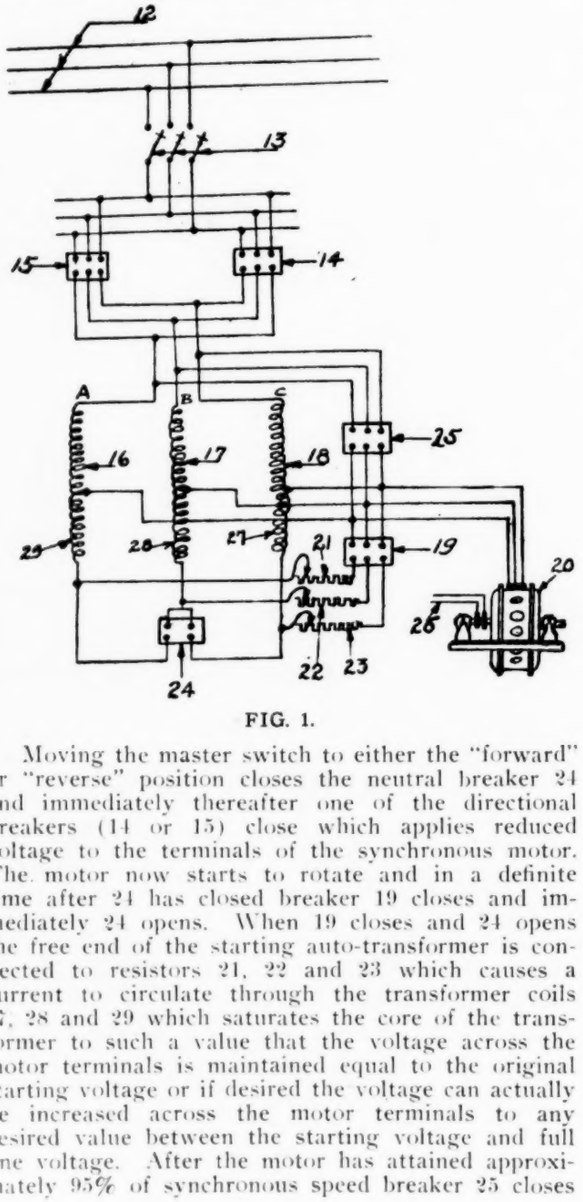

FIG. 1.

Moving the master switch to either the "forward" or "reverse" position closes the neutral breaker 24 and immediately thereafter one of the directional breakers (14 or 15) close which applies reduced voltage to the terminals of the synchronous motor. The motor now starts to rotate and in a definite time after 24 has closed breaker 19 closes and immediately 24 opens. When 19 closes and 24 opens the free end of the starting auto-transformer is connected to resistors 21, 22 and 23 which causes a current to circulate through the transformer coils 27, 28 and 29 which saturates the core of the transformer to such a value that the voltage across the motor terminals is maintained equal to the original starting voltage or if desired the voltage can actually be increased across the motor terminals to any desired value between the starting voltage and full line voltage. After the motor has attained approximately 95% of synchronous speed breaker 25 closes which connects the motor to the line and also shorts out the auto-transformer. After breaker 25 has closed the field is applied and the motor is ready for service.

A synchronous motor during the starting period has a power factor of approximately 35% lagging. If we draw a lagging current through a reactance such as 16, 17 and 18 in Fig. 1 the voltage across the motor terminals will decrease below the starting voltage applied to the motor terminals if you do not saturate the core of the transformer by means of the resistors 21, 22 and 23 when breaker 24 is open. This principle is just the reverse of the synchronous converter problem wherein reactance is placed in the A.C. leads of the converter and by causing the converter to take a leading current the voltage on the D.C. side of the converter is increased.

If field is applied to the motor before breaker 24 opens, breaker 19 and the resistors can be eliminated. This is due to the fact that sufficient field can be applied which will cause the motor to take a leading current which will either maintain the voltage across the motor or in some cases, the voltage will actually increase across the motor terminal after the field is applied.

A scheme which eliminates breaker 19 and the resistors has the disadvantage in that the motor is pulled in step at reduced voltage and since the "pull-in-torque" of the motor varies as the square of the voltage the synchronizing power of the motor is considerably reduced. By using breaker 19 and the resistors the motor is pulled in step at 100% voltage as explained previously and thereby the maximum synchronizing power or maximum "pull-in-torque" is obtained.

With Mr. Umansky's permission I would like to supplement his remarks in regards to the use of synchronous motors for driving reversing mill generators. I do not know if the General Electric Company have ever supplied any synchronous motors for driving reversing mill generators, however, about 1½ years ago the Westinghouse Company made their first installation in the Pittsburgh District using a synchronous motor for driving two generators operating in parallel and supplying a reversing mill motor.

Twenty-fifth
Annual Convention
and
Iron and Steel Exposition
June 17th to 22nd, 1929
WILLIAM PENN HOTEL,
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*Heat Resisting Alloys and Their Use in the Steel Plant**

By J. D. CORFIELD†

IT is the purpose of this paper to discuss that class of present day metals commonly, though sometimes erroneously called "Heat Resisting Alloys," with particular reference to the application of those metals within the steel industry.

EARLY HISTORY

Such alloys first came into existence on a commercial scale some twenty years ago as the result of experiments conducted by A. L. Marsh of Detroit. About that time it was realized that the extensive use of electricity as a source of heat energy would be seriously handicapped unless metals could be produced capable of withstanding the high temperatures developed in the resistors or heating elements. It was not feasible to employ gold, silver, platinum, or other rare metals because of their prohibitive cost and, in some cases, because their electrical characteristics were unsuited. The problem, therefore, became one of alloying less expensive metals known to possess certain desirable properties of chemical stability and resistance. Alloys of Nickel and Chromium were soon found to meet these requirements most satisfactorily. Practically all subsequent development has involved the use of these two elements and of the so-called heat resisting alloys in widespread use today, all will be found to contain large and varying percentages of at least one. With few exceptions both are present.

Although the earliest alloys were composed of practically 100% combined Nickel and Chromium in the proportions of 80% Nickel and 20% Chromium, it was not long before further investigations resulted in the discovery that considerable Nickel could be sacrificed and iron substituted without materially altering the operating characteristics of the alloy . Thus the alloys were changed to include 20% Fe. in combination with 15% to 20% Cr. and 60% to 65% Ni. In fact, it was from this alloy that the first castings were made, these being in the form of thermocouple protection tubes.

The field of usefulness for the alloy soon broadened to include not only electrical requirements but a multitude of other uses as well, such as pots for molten lead and cyanide, containers for carburizing and annealing, thermocouple protection tubes, skid rails and other parts used in connection with the continuous furnace. As a matter of fact, while the continuous furnace was not unknown prior to the introduction of heat-resisting alloys, its field of usefulness was greatly widened by such metals and many processes considered quite commonplace today would have been economically, if not wholly, impossible without the aid of metals capable of withstanding oxidation, deformation, and in some cases, corrosion at operating temperatures.

NICKEL CHROMIUM ALLOYS

While the primary object of Marsh's experiments had been to provide a high degree of surface stability at elevated temperatures, the use of alloy castings for other than electrical purposes soon brought to light a manner of failure quite apart from surface deterioration in the form of mechanical failure due to lack of physical strength. This led to investigation of still other combinations of alloys during which work many interesting facts were disclosed. It was found that while nickel is useful in adding chemical stability to the alloy, its principal function is that of a strengthening and toughening agent. Furthermore, that even in this respect, its usefulness ceases at about 35%, beyond which point —for structural uses at least—the additional resistance to oxidation provided by further additions of nickel is obtained at a cost out of proportion to its value and at a sacrifice of high temperature strength. Consequently a new series of alloys was introduced containing 35%-40% Ni., 15%-20% Cr. the remainder, iron. These are sometimes called the "balanced alloys."

So far, we have been considering alloys intended for use under conditions where resistance to oxidation plus adequate physical strength only must be provided. There are, however, two other forms of destruction which must sometimes be considered in the selection of a suitable alloy: These are: abrasion and corrosion. Practically all heat-resisting alloys have the property of resisting abrasive wear, both at normal and elevated temperatures, some, of course, more than others but as a class, they compare quite favorably with the best grades of steel sold expressly for this purpose. Where corrosion is present at elevated temperature it is necessary to select an alloy with thought of the corrosive agent with which the metal will come in contact. For use under most corrosive conditions that can exist at high temperature an alloy containing 12%-15% Ni. and 25%-30% Cr. may be used but is recommended only where the corrosive agent is of a nature which precludes taking advantage of the very great high temperature strength provided by the balanced alloys which as stated before contain 35%-40% Ni. and 15%-20% Cr.

It is not necessarily true that the balanced alloys, because of their relatively high nickel content, are unsuitable for use in contact with sulphur in any of its forms. This was illustrated recently when the author examined several pickling tank racks which had been in almost daily use for two years without visible injurious result. The pickling medium in this case was a 7% H_2SO_4 solution maintained at 125°F. The racks were made of an alloy containing 35% Ni. and 15% Cr. Not infrequently,

*Presented before Mid-Winter Conference, Combustion Engineering Division of the A. I. & S. E. E., at Pittsburgh, Pa., January 23, 1929.

†Engineer, Michigan Steel Casting Co., Detroit, Mich.

failures are reported which are not properly failures of the alloy as such but are the result of attacks upon individual parts of the alloy which, during solidification, have migrated to or near the surface area causing the metal to become more a mechanical mixture than a true alloy with its component parts proportionately distributed throughout its mass. The more complex the alloy, the greater will be the liability to this condition and great care must be exercised to guard against its existence, especially where the castings are intended for use in a corrosive environment.

The alloys already described do not by any means constitute the entire group of Nickel-Chromium alloys marketed under various trade names, but may be regarded as representative of general classes of alloys in which changes may be made to emphasize some particular characteristic.

CHROME-IRON

In the preceding paragraphs we have discussed those alloys containing both nickel and chromium and have made no mention of another class of metals known as the chrome-irons. This class of alloys contains chromium up to 30% and carbon as high as 3%. The chrome-irons should not be confused with the stainless irons which may contain equally as much chromium, but do not exceed .12 carbon. Chrome-irons are extremely resistant to most forms of corrosion, but inasmuch as the element which imparts this property also renders a high degree of resistance to oxidation, the chrome-irons have been used extensively in high temperature work, particularly where surface losses may result from corrosion as well as from oxidation. They lack, however, the great high temperature strength of the nickel-chromium alloys, and are quite brittle.

VARIETY OF ALLOYS

From the foregoing it is evident that there is no one alloy which may be used under all operating conditions, and that the selection of a metal for any given application must be based upon an analysis of the individual conditions existing, and the requirements of the job. For example, an alloy that would be quite rapidly destroyed in a strongly oxidizing atmosphere at 1900°F. might be used with safety at 2100°F. in the same furnace if reducing conditions obtain. On the other hand, a metal capable of withstanding 1900°F. in a neutral or slightly oxidizing atmosphere might be quickly destroyed at as low as 1600°F. under reducing conditions if the fuel contained a high per cent of sulphur. These facts are well illustrated in the case of roller bottom sheet normalizing, annealing, and pack heating furnaces where alloy discs, shafting, and chain are used for the purpose of conveying work through the furnace. It is thus apparent that temperature alone is not the governing factor in determining the suitability of an alloy.

In view of the widely differing conditions under which metals are called upon to serve, manufacturers have found it necessary to develop a variety of alloys, each suitable for use under a given set of conditions. Because the various alloys on the market have been sold largely under trade names, users have been somewhat slow in classifying them according to analysis. If the buyer knows the properties of various alloy combinations, he is in a position to buy and pay for only as much protection as he needs. Where 30% combined Nickel and Chromium will stand up under his requirements, it is as foolish to pay for 60% combined Nickel and Chromium as it is to buy a 10 H.P. motor for 5 H.P. service. The time is close at hand when heat-resisting alloys will be sold under standard specifications similar to those used by the S.A.E. and others in classifying more common grades of structural alloys.

ALLOYS OF FUTURE

There is no reason to believe that all possible combinations of the alloy forming elements have been discovered, nor that the alloys of the future will not be infinitely superior to those of the present time. Recent developments have disclosed the fact that additions of tungsten result in a marked improvement in both the physical properties and chemical resistance of the alloys. The increasing use of this element may be expected. If a method of overcoming the destructive effect of aluminum on the physical properties of the alloy can be found, it may be possible to take advantage of the increased refractory properties imparted by additions of this element.

PHYSICAL PROPERTIES

A curve showing the tensile properties of an alloy of the following analysis is reproduced herewith: (Fig. 1)

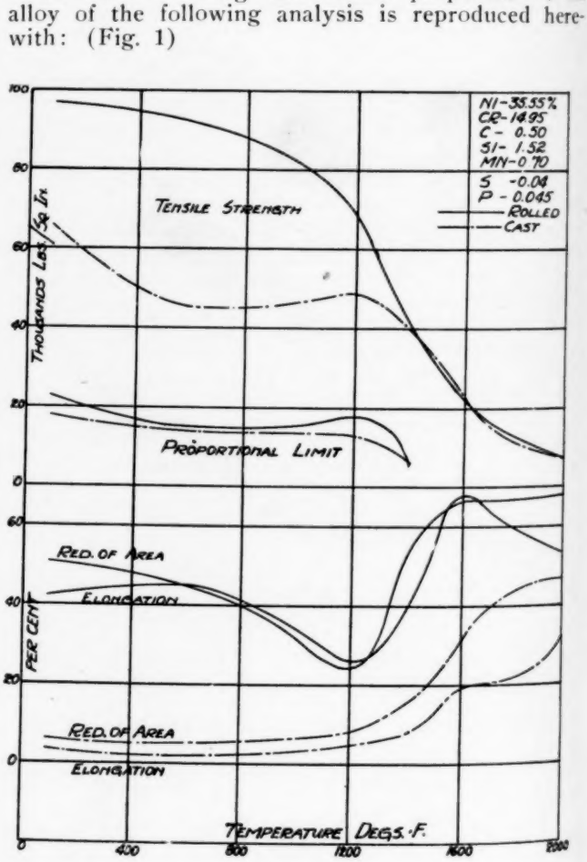

FIG. 1.

Ni.—35.55	Mn.— .70
Cr.—14.95	Sul.— .04
C.— .50	Phos.— .045
Si.— 1.52	

These values were obtained under quick-pull conditions and do not represent the ability of the alloy to carry sustained loads for long time periods. The latter values are exceedingly difficult to obtain although at the present time work is in progress during which test pieces are being stressed at various elevated temperatures for periods up to 5000 hours. In designing alloy structures it is common practice to use safety factors up to 60 in the higher temperatures, up to 40 in the intermediate ranges, and up to 25 in the lowest ranges at which the use of alloys is justified.

Comparison of the values shown by the curves of Fig. 1 with those of various other alloys at corresponding temperatures is purposely omitted because, in most cases, the author was unable to obtain a complete analysis of the alloys represented, neither was he able to obtain a report indicating the procedure followed in making the tests. Additions of silicon and carbon for example have a very pronounced effect on the high temperature strength of the alloy, even though nickel and chromium remain constant. Likewise, in high temperature testing, results are greatly influenced by such factors as soaking time, rate of pulling, and others. This explains the discrepancies which have been frequently noted regarding the differences in values supposedly representative of the same alloy. At the present time there is a committee engaged in studying the action of metals at high temperatures and it is expected that this committee will work out a procedure which will constitute a standard method for use in future high temperature tensile testing.

In making the determinations shown by the curves of Fig. 1, all work was done on a 50,000 pound testing machine. Standard .505 inch diameter test pieces with threaded ends were used.

Tensile strength, breaking strength, proportional limit, elongation, and reduction of area were determined for the cast and rolled metal at atmospheric temperature 600°, 1200° and 1400°F. No attempt was made to determine proportional limit values at the higher temperatures.

In the tests made at elevated temperature the test bar was held at temperature for 30 minutes before pulling the bar. Temperature measurements were made with base metal couples and a portable potentiometer. The couples were calibrated against a standard platinum, platinum-rhodium couple previous to the tests.

A complete temperature survey or calibration was made of the two furnaces used in the tests. These calibrations were made with the test bar in place in the machine, temperature readings being made at such as to give the temperature variation over the gauge length of the test pieces. Temperature readings were taken at both shoulders of the test piece and at the center, both at the surface and inside, or at the center of the test pieces. The test pieces used for calibration had ⅛" diameter holes drilled axially from each end, one extending to the center, the other to a shoulder for insertion of the thermocouples. The beads of the thermocouples at the surface were wired to the test bar. In the actual tests the bead of the thermocouple was wired to the test bar, insuring its remaining in position, and in contact with the surface of the test bar.

Two furnaces were used, one for temperatures through 1400°F. and the other for temperatures of 1600°F. and up. The principal difference in the furnaces was the use of heavier heating element and a larger insulating chamber for the furnace used at the higher temperatures. The heating, or furnace chamber proper was three inches in diameter in each furnace. The general arrangement of the furnace, extensometer grip, and thermocouple is shown by Fig. 2.

At 2000°F. only the calibration at the center of the test bar is made.

In carrying out the tensile tests, corrections for temperature were based on the differences shown by the two thermocouples at the center of the bar. That is, in making the tests at 1200°F. the temperature as indicated by the thermocouple in contact with the surface was actually 1240°F. Similar corrections were made for the temperatures on the other tests.

HEAT TREATMENT

Alloys of the heat-resisting class are essentially

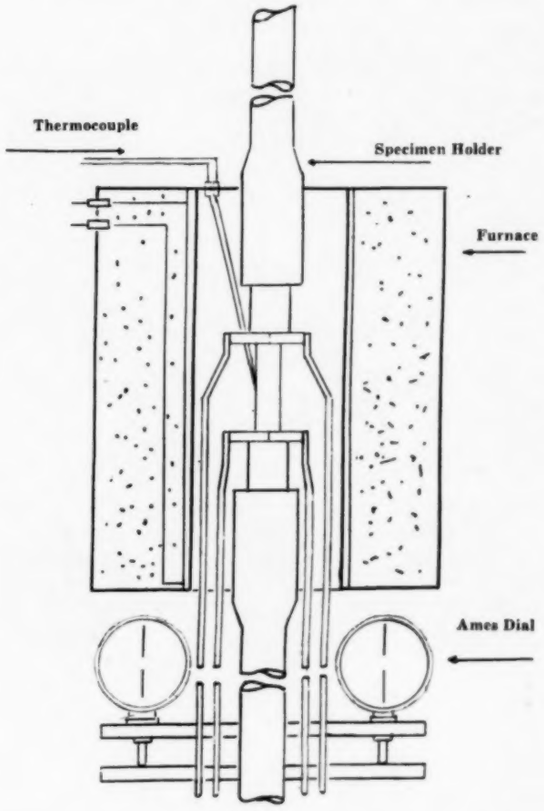

FIG. 2.

austenitic and do not respond readily to any known heat treatment. Figues 3, 4 and 5 show alloys which have been photographed in the "as cast" condition represented by (a), after slow cooling from 1650°F. (b), and after water quenching from 1650°F. (c). The three photomicrographs were taken of the same specimen before, between, and after being

given the treatment noted above. The specimen shown by Fig. 3, contained Ni. 33.73, Cr. 15.27, C. .60, Mn. .30, Si. 1.63. Fig. 4 shows an alloy containing Ni. 8.45, Cr. 18.41, W. 3.73, C. .88, Mn. .48, Si. .61.

(a) As Cast. (b) Slow Cooled From 1650F. (c) Quenched From 1650 F.

FIG. 3.

Fig. 5 shows an alloy of the following composition: Ni. 11.88, Cr. 29.77, C. .80, Mn. .61, Si. 1.50.

DESIGN

In designing castings and structures intended for use at elevated temperatures, it is well to keep in mind that sections and shapes are dictated by many factors other than physical strength alone. Not the least of these is, a proper regard for the foundry problems involved in producing sound castings. It is quite obvious that any design which presents strong liability to excessive shrinkage strains should be avoided. Even microscopic defects which in castings of ordinary materials intended for mechanical uses at normal temperature would be unobjectionable may promptly spell disaster in the case of castings for use under high temperature, for it is at these, the points of least resistance that the terrific forces of thermal expansion manifest themselves.

(a) As Cast. (b) Slow Cooled From 1650F. (c) Quenched From 1650 F.

FIG. 4.

(a) As Cast. (b) Slow Cooled From 1650F. (c) Quenched From 1650 F.

FIG. 5.

In Fig. 6, we have a good example of a casting in which full advantage is taken of the natural rate and progress of freezing. This casting is molded open side down, the metal being introduced through two gates located at diametrically opposite points of the rim and rises through the tapering section

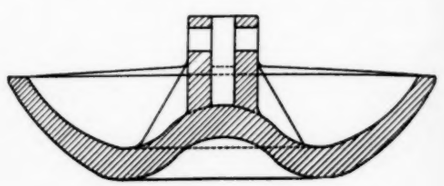

FIG. 6—Mushroom Valve.

until the feed heads are filled. The gradually increasing section provides for the proper regulation of the cooling phase which progressing upward satisfies its shrinkage demands from the fluid section above drawing lastly from the feed heads. The uniformity of cooling progress has a very important bearing upon maintenance of predetermined shrinkage fixed in the pattern.

Incidentally, there is another reason for the heavier section at the bottom of the casting used in this illustration. This is to provide additional protection against the action of the impinging gases in washing away the protecting film of surface oxide.

Many castings that cannot be designed to permit cooling at a uniform rate can be made to do so by the proper use of shaped and standard shills at points where sectional differences occur.

Often, it is necessary to design castings with sections much heavier than required for adequate physical strength. In the case of large I Beams, for example, it is essential that sufficient body be provided to enable the castings to pull themselves together against the fractional resistance imposed by the sand.

An interesting example of design is shown by Fig. 7, which is that of a large skid shoe. The upper left drawing shows how the casting was originally made. Note that the bead shown on the water-cooled pipe was carried the entire length of the casting which required that the metal section at the nose terminate in a feather edge. The hottest temperature zone to which the piece was subjected

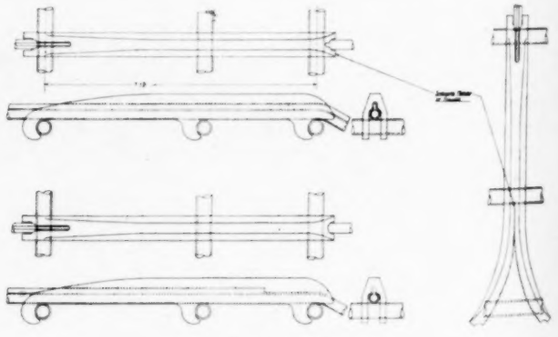

FIG. 7—Skid Pipe Shoe.

was at this point. In other words the greatest thermal expansion stresses were found at a point where the section was least able to withstand them. The pattern was made in two symmetrical halves split at right angles to the wearing surface. Thus, the casting had to be molded on its side with the parting in the center of the wearing face. When

the castings were placed in service a crack would soon develop and would progress along the parting line, causing the shoe to take the shape of a huge Y, as indicated by the sketch at the right.

In correcting the above condition it was merely necessary to remove the bead from the water-cooled pipe a distance great enough to permit the addition of a heavier and more adequate metal section at the nose of the casting. Instead of bringing the inside curved portion of the nose to a sharp edge, a sweeping radius was used. The next step was to construct a new pattern as a solid piece having aluminum inserts dovetailed for the protruding ends of the hooks. This permitted molding so that the parting came at a point where temperatures were least severe. The correct design is shown by the sketch in the left hand corner.

It is quite apparent that ample clearances must be provided to allow for the changes brought about by thermal expansion. Where unequal heating is unavoidable it is very desirable to design a number of smaller castings which may be assembled to form a single operating unit, each part being free to expand at a rate proportional to the temperature it receives.

GENERAL USES

In general, high temperature alloys should be used (1) wherever metals must serve under temperature high enough to cause replacement of iron or steel due to surface losses through oxidation or corrosion; (2) wherever loads must be supported under temperature for long time periods; (3) wherever both loads must be supported and surface losses reduced to a minimum; (4) wherever abrasion is present at high temperature. Examples of each of the above are:

(1) Carburizing and annealing containers, dampers, reversing valves, etc.
(2) Checker brick supporting plates, core plates, etc.
(3) Heating furnace skids, shafting for roller bottom furnaces, chain conveyors, lead pots, cracking still beams, etc.
(4) Rolling mill guides, rolling mill plugs, pipe balls, poppet valves, etc.

Group (3) comprehends a large majority of uses and includes all applications wherein the high temperature strength of the alloy must be considered along with its surface stability.

STEEL PLANT USES

The motor industry and builders of industrial furnaces have from the beginning of the industry been the largest users of high temperature metals. Of recent years, the introduction of these alloys into the steel plant has demonstrated incalculable saving, especially where their use has resulted in the elimination of water-cooling.

Tracing the course of steel through the various steps in its development we come first to the blast furnace, where heat-resisting alloys serve as blow-pipes, hot blast valves, and valve seats. Ultimately, it is hoped to substitute metallic recuperators in place of the massive refractory regenerators within the stoves.

Fig. 8 is that of a blow pipe intended to conserve much of the heat losses that take place by radiation where the pipes are exposed to air in the space between the leg-pipe and tuyers. These losses are greater than generally appreciated, often amounting to the equivalent of several tons of coke per furnace, per day.

Leaving the blast furnace, we come next to the open-hearth where the use of high temperature metals is confined to reversing valves, either in replacing the water-cooled dampers of modern equipment or the butterfly of the old system of reversing. It is unlikely that metals will ever be developed on a commercial scale capable of withstanding the temperatures at which the gases enter the regenerators, and for this reason alloy metal recuperators will never entirely displace the principle of regeneration in open-hearth practice. However, there is no reason why, after cooling to approximately 2000°F. the gases should not then enter a metallic recuperator from which the preheated air may pass to the proper checker chamber.

At the soaking pit we find alloys serving as reversing valves of the mushroom or saucer type where they have taken the place of both water-cooled and dry cast iron valves with great economy in either case. Here also we find gas regulating valves, waste heat dampers, and alloy burner parts.

The ingots leaving the soaking pits will be reduced to blooms, billets, slabs, and sheet bar. If they are reduced to billets, they may pass through alloy guides and thus will be less likely to become scratched during their journey. The special alloy guide has greatly added to the efficiency of the continuous mill by reducing delays caused by frequent changing of short-lived chilled and steel guides and by reducing guide scratches. It is sometimes difficult to anticipate the proper alloy to use in connection with various grades of rolled steel and for this reason it frequently becomes necessary to experiment with several alloys until one has been found that is suitable for the work at hand. Where this has been accomplished, results by comparison with more common materials are sometimes phenomenal. A recent report from one mill stated that one pair of alloy delivery twist guides had given service equal to that of 200 pair of chilled iron guides, although chilled iron had shown the best results of any material used prior to the introduction of alloy guides.

The billets may be further reduced to rods but will first require reheating. In the reheating furnaces heat-resisting alloy skids may replace water-cooled pipes. After again passing through alloy guides, the billets, now rods may be still further reduced by drawing into wire. If so, the coils should be annealed in alloy containers or the wire may pass through a patenting pan which should be of similar alloy.

Slabs and sheet bar will also require reheating in either stationary or continuous furnaces before being rolled into sheets and plates. Slab heating furnaces are operated at temperatures too high to permit the use of alloy skids, but when black spots result where the slabs engage the water-cooled pipes it is often possible to overcome this difficulty by using an alloy skid pipe shoe similar to that shown by Fig. 7. In this way the slabs are raised several inches above the water pipe during the last six or eight feet of travel which thus permits those points

of the slab that have been in contact with the skids to reach approximately the same temperature as the balance of the metal before being discharged. The alloy castings, receiving the advantage of the cooling effect of the water pipes have very great service life.

In the plate, sheet, and tin plate mills we find the roller bottom annealing, normalizing, and pack heating furnace equipped with alloy shafting and discs. By comparison with the water-cooled shafting of former equipment it is not uncommon to discover fuel savings alone amounting to 30% of that necessary to maintain the same chamber temperature in a furnace using water-cooled shafting. When improved heating and elimination and maintenance of equipment necessary to supply water are considered the total economy effected by the use of dry alloy shafting may sometimes reach as high as 50% of previous costs. Equally impressive savings have been reported where alloy chain conveyors have been substituted for discs mounted upon water-cooled shafting as a means for conducting work through the furnace.

In the seamless tube mill alloys are finding a broad field of usefulness as heating and annealing furnace parts, rolling mill plugs, piercing points, and guides. The welded tube mills are indicating a strong interest in alloy pipe bells and pipe balls because of their ability to resist abrasive wear at high temperatures.

The uses already described do not by any means exhaust the possible use of heat-resisting alloys throughout the steel industry but, with one or two exceptions are applications which have progressed beyond the experimental stage and are at the present time in more or less general use.

The alloy business is not one which will permit of forced sales methods. Each problem must be considered on its individual merits, requiring a careful engineering analysis in practically every instance. Conclusions based upon such analysis may spell the difference between subsequent success or failure under operating conditions. No amount of metallurgical hocus-pocus or guaranteeing can be counted upon to solve any of the fundamental engineering problems involved, nor will the guarantee extend to the point of assuming the expense of costly shutdowns or the cost of labor and supplementary material required for repairs.

Because of unfortunate and unbalanced economic conditions that do not permit the steel-maker to realize the full profit to which he is entitled on the sale of his product he is therefore interested in anything that may assist him in widening the gap between cost and selling price. Heat-resisting alloys, intelligently applied, are a means which can help him achieve this end. This, after all, is the only excuse for the alloy business, insofar as the steel-maker is concerned.

Discussion

Dr. John Unger†: The paper has a number of very admirable points. Those of you who have followed these special alloyed steels composed principally of chromium and nickel, know what a wonderful field there is for material of that kind.

I believe there is an impression in the minds of the average persons that these alloy steels are good for all purposes. They have some very excellent physical qualities, and by "physical qualities" I mean those of strength. They also have some very excellent chemical resisting qualities. I mean by that resistance to the action of gases, or acids, or fluids of any kind which might corrode the material. The average opinion seems to be that they are also resistant to oxidizing influences by gases given off by combustion. Whether a reasonably cheap alloy has been produced or ever will be produced that will combine all those qualities is very doubtful.

The use of these special alloys is growing, as you all know. They are beginning to be used very largely in the arts. The thing that it seems to me will prevent their universal production is the question of cost. In order to make the alloys of good quality, they require a high percentage of nickel and chromium, chromium being the principal element which gives peculiar qualities.

Even if there were other methods whereby the metals might be produced cheaper, the very fact that the chromium is a comparatively rare metal, will always maintain the cost at a high figure.

†Director of Research, Carnegie Steel Co., Pittsburgh, Pa.

J. S. Huston*: This is an extremely interesting paper, and a very valuable one in pointing out the numerous economies that can be effected in industrial work by the use of heat resisting steels.

Under the heading Physical Properties, Mr. Corfield brings out that alloys of the heat resisting class are essentially Austenitic, and as such do not respond readily to any known heat treatment.

Previously, under the heading Nickel Chromium Alloys, he brings out that failures with these alloys are often the result of attacks upon individual parts of the alloy which have migrated to or near the surface area, causing the metal to become more a mechanical mixture than a true alloy.

If the alloy is made perfectly Austenitic should there be any such mechanical mixture?

Austenitic steels after any forging or rolling operation, and particularly after cold work, have their grains more or less distorted, and, in this condition, are not perfectly resistant to corrosion and oxidation at higher temperatures.

After any such operation it has been brought out by Dr. W. H. Hatfield of Sheffield and others, that Austenitic steels should be treated to correct this distortion, usually by heating to 1000° C., and cooled in either water or air.

In heating heat resisting steels preparatory to forging or rolling great care should be taken to see that the proper temperature range for working each particular grade of material is not exceeded; otherwise, the metal may be ruined by oxidation. It is

*Plant Metallurgist, Lukens Steel Co., Coatesville, Pa.

wise to keep very accurate pyrometric control on the heating furnace.

A very good point is raised under the heading Variety of Alloys that the selection of a metal for any given application must be based upon service conditions.

Under the heading Physical Properties, the statement is made that among factors influencing results in high temperature testing is soaking time. The explanation for this is probably the slow heat absorption of the material as compared with ordinary Carbon steel.

The uses to which heat resisting steels can be put, which are brought out in this paper, are especially notable in their application to the steel plant. Isn't there also a potential development for these alloys for high pressure vessels, where the metal is subjected to high stresses and sometimes severe corrosion at elevated temperatures?

F. H. Loftus*: I should like to know the proper alloy to use for pyrometer tube sheathing where producer gas is the fuel. Also if the effect of the gas containing sulphur upon the alloy is the same whether the gas is in motion or not.

J. D. Corfield: Except where the tubes are introduced through the side walls, and supported only at one end, the question of physical strength is not entitled to much consideration. Therefore, any alloy capable of withstanding the corrosive or oxidizing effect of the furnace gases may be used. With no information at hand except that producer gas is the fuel, I should recommend an alloy having a high chromium content, say 30 Cr.—15 Ni.

The other part of this question may be answered in the affirmative. The life of any alloy is greatly influenced in relation to the flow of the gases with which it comes in contact. The higher the velocity, the greater will be the surface loss. This is especially true if small amounts of solid matter be present in the gases, which impigning on the surface of the alloy have an effect similar to that of a sand blast, washing away the protecting film almost as quickly as it is formed.

M. H. Mawhinney†: I should like to ask Mr. Corfield if any data has been developed on the effect of machining alloy castings. That is, the comparison between the same casting of the same analysis with the natural effect of the skin on the casting, and the same casting after the skin has been removed.

J. D. Corfield: Machining of alloy castings is not detrimental to their service life. It is very true that a casting that has just been removed from the mold will be covered with a film of oxide corresponding to that which develops in service. However, during subsequent cleaning operations, including sand-blasting, grinding, chipping, and tumbling, it is quite apparent that this film will be completely destroyed. There can be no doubt of the fact that the life of an alloy casting is in a large measure due to the protection it receives from the skin which forms upon its surface, but it is the skin which develops during service that accomplishes this result. It should also be remembered that the alloys we have been discussing have in themselves a certain chemical inertness which contributes to their service life.

H. V. Flagg*: I should like to ask if there is any data on the relative corrosion of different fuels, fuel oil, producer gas, natural gas, etc., upon an alloy of any composition and what the relative corrosion would be.

J. D. Corfield: Of the gaseous fuels, alloys are least affected when serving in the products of combustion resulting from the use of natural gas. The action of producer gas varies greatly according to the analysis of the gas, particularly as regards sulphur content. The same may be said of liquid fuel. I know of no data of the nature requested that would be applicable to other than a given set of conditions. There are a few general rules, however, that should be borne in mind in the selection of a suitable alloy. One of these is that the higher nickel alloys should not be used in the products of combustion of high sulphur fuels (liquid or gaseous) when such fuels are burned under reducing conditions. In such cases the high cromium alloys are preferable even though their use necessitates some compromise in the matter of physical strength. This rule does not necessarily apply where oxidizing conditions prevail.

T. B. Bechtel: I noticed in the sketch you showed what was evidently a skid rail, a water-cooled rail with an alloy shoe on it. Does that represent to your knowledge the latest development in skid rails for reheating furnaces and things of that sort? Also, what precedes the water-cooled section? Can you use the straight alloy rail toward the charging end of the furnace?

J. D. Corfield: The skid pipe shoe to which you refer is intended for use where temperatures are too high to permit the use of straight alloy castings, but where it is necessary to deliver stock to the rolls free from black spots resulting from contact with the water-cooled skids. It would be possible to use alloy skids in this furnace from the charging sills to a point where the temperature reaches 2000° F. or so, water-cooled skids running from the end of the alloy to the discharge end of the furnace.

T. B. Bechtel†: You showed water-cooled cross rails to take the thrust of the alloy shoes. Have you found that that works allright in fairly large furnaces, say heating 12" squares or something like that?

A. L. Culbertson**: I thought I might be able to explain a little about the skid shoes since I am familiar with the furnace installation for which they were originally designed. This particular furnace had water cooled skids running full length of the furnace since it was desired to use split flame firing with flame both above and beneath the slabs being heated. This furnace heated slabs for a plate mill and no black spots were desired on the discharge slab. At the discharge end of the furnace there was no brickwork or piers for supporting the skid pipes

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†Electric Furnace Co., Salem, Ohio.

*American Rolling Mill Co., Middletown, Ohio.
†Electric Furnace Co., Salem, Ohio.
**Rust Engineering Company, Pittsburgh, Pa.

since maintenance would be too high on them. Water cooled cross pipes were used to support the skids at this point and not only eliminated the necessity of brick piers, but also provided free circulation for the gases beneath the steel. The skid shoes were hooked over the cross skid-support pipes merely because the cross pipes were already there.

J. D. Corfield: The water-cooled cross-rails were put there primarily to help support the skid rails which are quite heavily loaded and have no other support near the discharge end of the furnace due to firing from above and below the work. They are thus made to serve a double purpose.

M. H. Mahwinney: I should like to ask one more question. In heating cast iron boxes, carried on alloy rails, a roller rail, say where there is some movement between the parts of the alloy at 1450, would the oxide given off, dropping off from the cast iron box, wear the alloy? Is the oxide sufficiently soft to have no effect, or would it have an abrasive effect on the alloy rollers.

J. D. Corfield: There is undoubtedly some abrasive effect resulting from this condition. If scale enters the bearings its most serious effect would be that of building up under the hubs of the rollers thus impairing their alignment. It is an easy matter to design these rails with enough relief in the bearings to allow the scale to work out. I know of several roller rail installations in which steel or iron containers are used, and have never heard of difficulties experienced as the result of scale causing excessive wear of the hubs on the rollers.

*The Isley Furnace Control**

By G. A. MERKT†

Introductory Explanations

THIS article is not intended to be a conclusive treatise but rather an heuristic description of observations and thoughts which have bearing upon an effort to interpret the operating performance of a regenerative furnace. Much research work and purely scientific treatment is still required to cover completely the complicated combination of chemical and physical processes involved in the operation of a steel furnace. The opportunity for fundamental analysis in this direction is particularly near to the Combustion Engineer on account of his training and also because of his intimate contact with both the operating and the management ends of the business. It is therefore to be hoped that this discus-

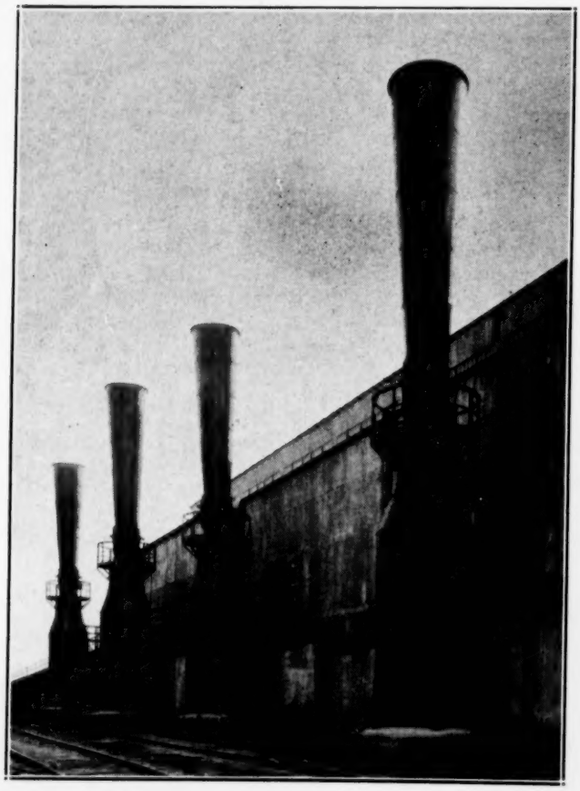

FIG. 1—Installation of Isley Furnace Control Apparatus on Two Large Open Hearth Furnaces.

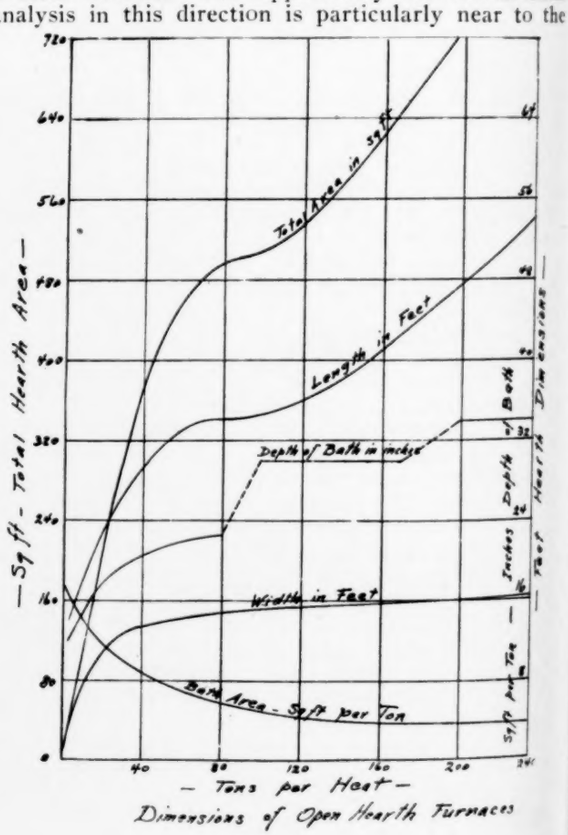
— Sq ft - Total Hearth Area —
— Dimensions of Bath & Hearth —
Total Area in Sq Ft
Length in Feet
Depth of Bath in inches
Width in Feet
Bath Area - Sq ft per Ton
— Tons per Heat —
Dimensions of Open Hearth Furnaces

FIG. 2.

*Presented before Combustion Engineering Division, A. I. & S. E. E. at Pittsburgh, Pa., January 23rd, 1929.

†Engineer, Morgan Construction Company, Worcester, Mass.

sion will incite fresh interest in systematic tests which are sufficiently complete in their scope of observation and records, so that some of the vague and unreliable rule of thumb notions which are still dictating in furnace design and operation may be properly revised and converted into reasonable laws.

It should also be kept in mind that we deal here not with the Isley furnace, but with the Isley Furnace Control, which constitutes a system of furnace operation rather than a type of furnace construction. Part of the principles of this system are as old as the art of making steel; other principles used may be traced back to the earliest technical work done in locomotive engineering. The peculiar combination of these principles and the particular arrangement used by Isley for controlling the speed and character of combustion is of comparatively recent birth. Primarily intended to replace the stack and the conventional form of reversing valves in a regenerative furnace, this novel arrangement of reciprocating balanced draft regulation was quickly discovered to have highly desirable properties relating to the orderly process of heat production and exchange and to its preservation and utilization.

Furnace Design

It is impossible to discuss the operation of a furnace system without coming in contact with the construction of the same and giving consideration to the influence of construction details with reference to the results obtained. The American trend of Open Hearth furnace dimensions indicates the use of a greater hearth area per ton capacity for smaller furnaces, and an almost constant width of the hearth for furnaces having more than 100 tons capacity. Larger furnaces therefore can burn but little more fuel per hour efficiently after reaching the maximum width. Only an increase in the height of the roof can give additional combustion space per linear foot of furnace length. There seems to be a decided change in furnace proportions clustered around the 80-ton capacity. This is probably due to the fact that the furnaces in the neighborhood of this capacity are beginning to get into the field of hot metal practice.

The checker chamber proportions change similarly as the larger furnace capacities are approached. The width of the chambers remains almost stationary beyond the 125-ton capacity. This is due to the difficulty of building arches of wide span and of obtaining proper distribution of the gases through the entire chamber width. The increase in height of the checker chambers also slows up towards the larger capacities. This is undoubtedly due to limitations created by the furnace plant itself. The length of the chambers increases considerably for the larger furnaces, which may be considered to have horizontal checker chambers rather than vertical chambers as far as the proportions of the chamber dimensions are concerned.

Horizontal chambers, however, must not be confused with horizontal checker brick arrangements. The term "horizontal checkers" is little appreciated and often is taken for horizontal chambers, or vice versa. The distinction between vertical and horizontal checkers, or checker brick arrangements, lies in the direction of the principal flue gas channels formed by these checkers. Short, but high, checker chambers should have a vertical checker brick arrangement, whereas very long chambers should have a checker brick arrangement, which will direct the flow of the gases horizontally, more than vertically. With natural draft and the absence of fans for air

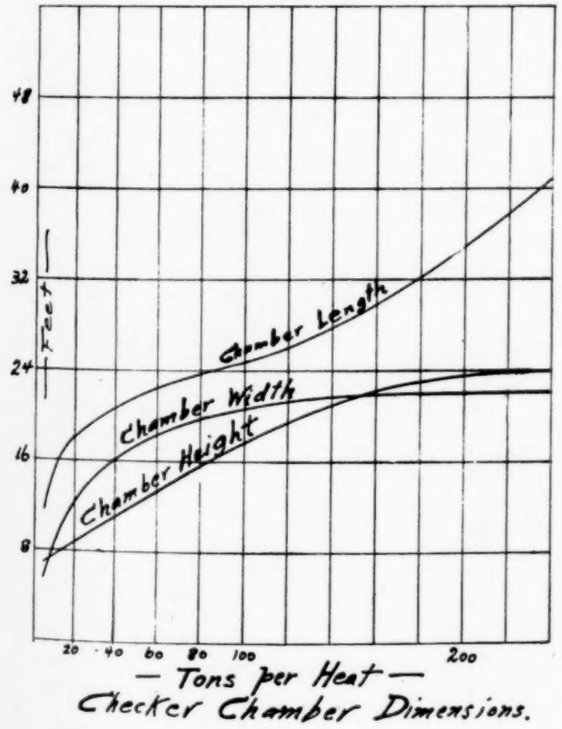

FIG. 3.

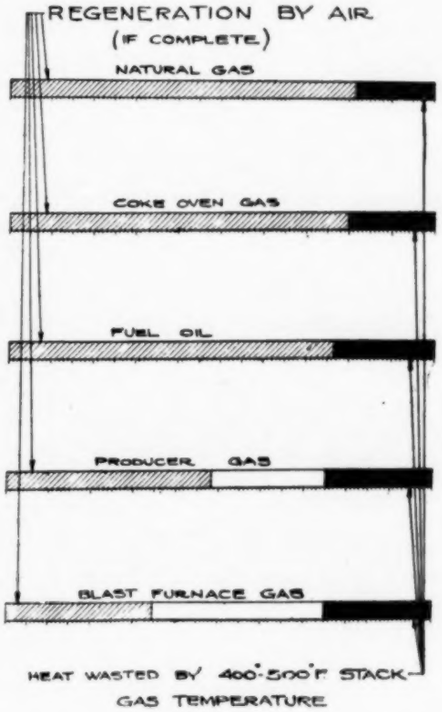

FIG. 4.

supply, vertical checkers are the correct arrangement, whereas for mechanical draft, the horizontal arrangement, extended as far as possible by auxiliary or secondary checkers, is an advantage, in that the effective path of the flue gases is hereby lengthened, thus gaining time and opportunity for losing temperature more completely to the heat storing material. In either case, the path of the gases through the chambers must be studied carefully and the checker brick so arranged that the gases have the tendency to cover the checker volume installed as completely as possible. Inactive portions, especially near the bottom, become dust catchers and are dead investments.

The checker mass distribution should be heaviest next to the furnace and become less and less voluminous towards the stack, where a lower flue gas volume is prevalent. The conductivity of the checker material and its specific heat, if it is chosen higher at the cold end, will improve the rate of heat exchange.

Temperature Exchange In Regenerators

If we examine the theoretical amount of waste heat released by an Open Hearth furnace (assuming perfect combustion and tight construction) we find that the theoretical amount of air required for various fuels would return to the furnace in some cases all of this waste heat, and in some cases a very large part of it. Assuming that it will be permissable to discharge the flue gases to the atmosphere at between 400 and 500°F., there will be a loss of 20 to 25 per cent of this waste heat which is unavoidable, thus leaving 75 to 80 per cent of waste heat available for regeneration of the air of combustion alone. Thus we find that for natural gas, coke oven gas, fuel oil and tar there is, if anything, a shortage of waste heat available in order to completely preheat the necessary air of combustion to the temperature at which the waste gases are released by the furnace. This condition is materially altered if we have incomplete combustion in the hearth chamber and if there is leakage through the checker or flue walls, or from reversing valves. The aim should therefore be to operate the furnace with a minimum amount of air necessary for complete combustion and the more we preheat this air to the temperature of the outgoing flue gases, the more nearly we will obtain complete combustion, in other words, the aim should be for perfect combustion.

There is a definite relationship between flame temperature, waste gas temperature, heating value of the fuel, and preheat of fuel and air or the air alone. This was first illustrated in diagram form by Dr. Bansen in his report under date of May 10, 1924, to the German Society of Steel Works Operators. By examining this diagram, we can easily observe the necessity of high preheat for the lower grades of fuel, if it is desired to obtain a flame temperature which will permit of a reasonable rate of melting steel.

Another illustration by the same author makes clear that with fuels which produce a greater amount of waste gas, or in a furnace system in which the waste gases are polluted with ballast of either outside air or moisture, it is necessary to work with a higher preheat than is the case with fuels or furnace systems which produce a lesser amount of waste gas per million B.T.U's. in the fuel. These

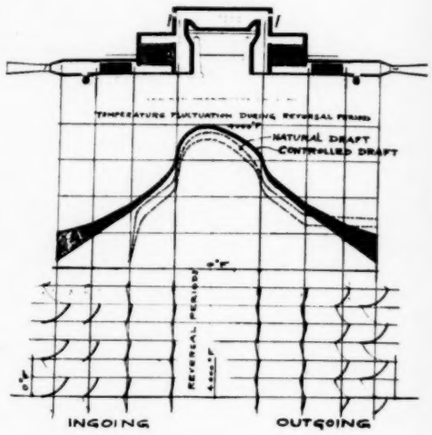

FIG. 5—Temperature Fluctuations During Reversal Period.

facts are not always appreciated by furnace operators, nor by those who are responsible for the selection of the fuel to be used in the furnace.

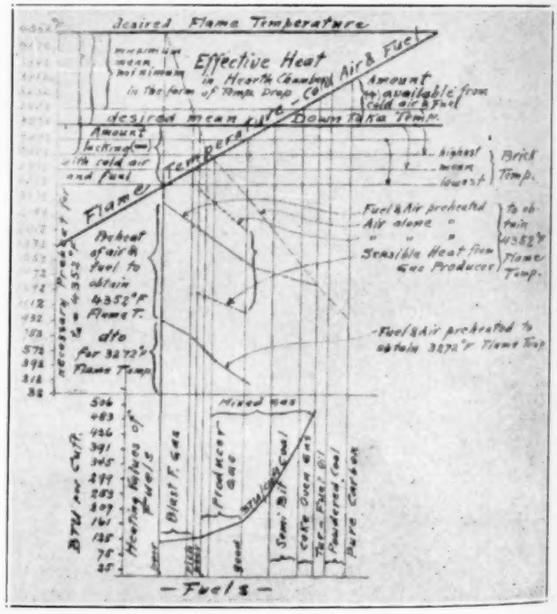

FIG. 6—Relation of Flame Temperature to Preheat and Heating Values of Fuels.

In order to make full use of the available heat from the waste gases, it is therefore necessary to correctly proportion the amount of air needed for combustion and to preheat the same to as high a degree as possible. In a regenerative furnace this is accomplished by an exchange of heat between the flue gases and the checker material and between the latter and the incoming air. It will therefore

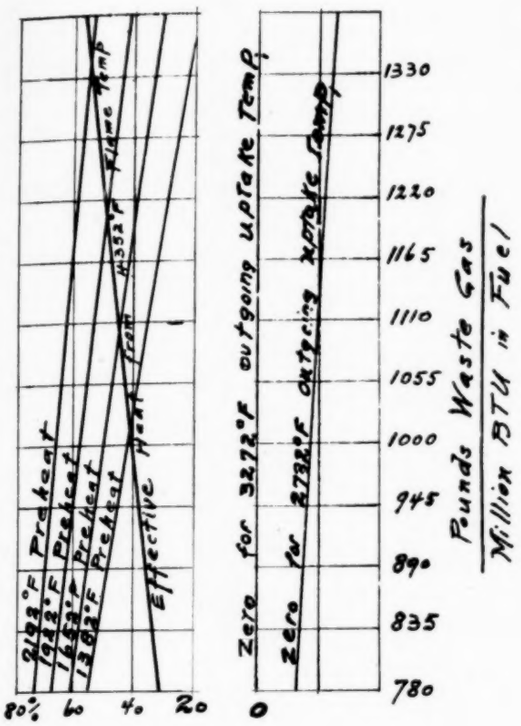

FIG. 7—Percent Heat Available in Hearth Chamber per 10^6 B.T.U. Fuel.

be interesting to consider the properties of the checker material necessary to make this exchange

	Sp. Heat	Heat Conductivity	Sp. Gravity	Product	Melting Point
Copper	.125	.920	8.93	1.027	1981
Aluminum	.236	.550	2.70	.350	1216
Wrought Iron	.115	.143	7.86	.129	2741
Cast Iron	.119	.111	7.03	.093	2327
Alundum	.191	.00833	3.63	.00578	3389
Crystolon	.186	.00982	2.87	.00524	3812
Clay Brick	.220	.00169	3.82	.00142	3050

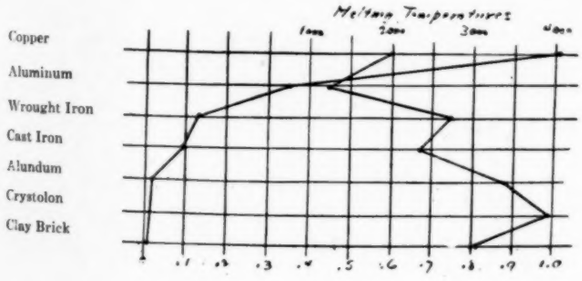

FIG. 8.—Index of Heat Pulsating Capacity of Checker Materials.

as efficient as possible. Inasmuch as this heat exchange in a regenerative system is effected chiefly but not solely by convection, i.e., by direct contact between the gases and the checker material, and since it is necessary to absorb the heat presented to the checker material to some depth below its surface, it is evident that high heat conductivity plays an important part. The amount of heat which any material can absorb is directly proportional to its specific heat and its mass. The latter can be represented by the specific gravity. The properties just mentioned contain, as you will note, one item which is depending upon the time element. If we therefore combine these properties into a product, we may obtain a picture which can be termed the "index of heat pulsating capacity," according to which the refractory materials are of the lower order and the metals by far of the higher order. But we have to do not alone with heat units but also with temperature and in some sections of the regenerative system the temperature is rather high. Checker material therefore must be chosen also with regard to its temperature resisting properties which may be expressed by the melting point. The melting or fusing point indicates the suitability of materials in various temperature regions, thus it may be assumed and readily supposed that metallic checkers can be utilized to advantage near the cold end of the circuit, whereas refractory material must, of course, be used at the hot end.

It is generally recognized that insulation against heat losses for some parts of the furnace system is a profitable investment. This cannot be emphasized too greatly. At the same time, it is to be kept in mind that there is a limit as to the extent to which the prevention of heat radiation may be carried. The fusing point of refractory material is fairly well known and any part of the furnace which is subjected to temperatures higher than this fusing point must be permitted to radiate some of the heat through the walls in order to avoid accumulation of temperature which will be destructive to the material used in construction.

Description of Isley Control Apparatus

There are, at the present time, two types of Isley Control units in use which differ from each other only in appearance, but not in principle. The original arrangement, known as the Double Tube type,

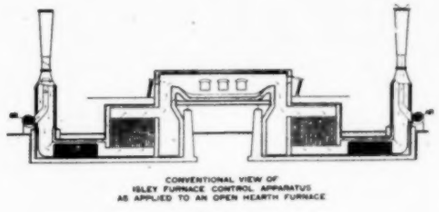

FIG. 9.

is the simplest form and is usually employed when changing existing furnaces to the Isley Control. This can be done without disturbing the furnace and the main checkers by connecting the latter directly to separate ejector tubes without interruption, and

as directly as possible. The short vertical ejector tubes are brick lined to the throats and have an extension of cone-shaped diffusers only high enough to lift the products of combustion over roofs or surrounding buildings. Standard types of fans, motor driven, deliver the air necessary for the ejection of the waste gases in one tube, while air for combustion is delivered to the furnace through the other tube. The proper quantity of air, in either case, is obtained by speed regulation of the motors, or by intake regulation of the fans. The butterfly dampers in the throats assist in the reversal of the direction of flow from or to the furnace. By means of draft gauges connected to the uptakes of the furnace, it is possible to balance the furnace for any rate of combustion desired, or possible. A pyrometer indicates and records the temperature fluctuation of the waste gases and the ingoing air from thermocouples which are inserted into the ejector tubes in the vicinity of the throats, i.e., at the cold end of the system. Temperature controlled indicator lights warn the operator when his furnace system is within 50° of the peak temperature, at which he should reverse his furnace. For intelligent operation and use of the control equipment, it is desirable to have a fuel meter by which the rate of fuel consumption may be observed.

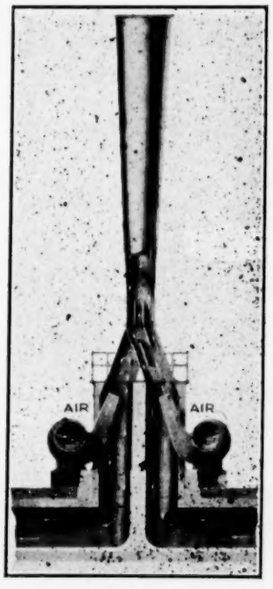

FIG. 10—Isley Furnace Control Single Type.

The Single Tube type Isley Control is basically the same as the Double Tube type, and is often preferred in new furnaces or where local conditions of available room, building construction, etc., may favor this arrangement. In this case, the single ejector tube, which is divided into two vertical compartments, is usually somewhere opposite the center of the furnace, and the main checkers are then connected to this ejector tube by flues which are brought together correspondingly. As in the Double Tube type, each side of the furnace has a separate fan, motor driven and controlled. The bifurcated throat box is constructed with louver type dampers for reversing the flow of air and waste gases. The throat contains a vane box for laminating the stream of gases to the single diffuser on top. The usual draft gauges and pyrometer are part of this equipment also, and the operation of the Single Tube type design in no way differs from that of the Double Tube type of Control.

Improvements Inherent With the Isley Control

The physical advantages of the apparatus and arrangements described are particularly attractive to the mill man. There is no mechanical equipment exposed to high temperatures since the fans are taking in cold air. There is a striking absence of heavy equipment, such as the conventional types of reversing valves, water cooled dampers, etc. There are no high stacks which must be periodically painted and repaired. There are no water seals with their troublesome maintenance. The control unit can be changed, if this should become necessary, while the furnace is in operation. A minimum of space is required. The entire outfit is simple to install and maintain, since it has all standard equipment, and it is easy to manipulate.

The advantages in which the furnace operator is particularly interested are of even greater importance. The furnace comes to temperature sooner when starting up. It is therefore found that less time is required for making bottom. On account of higher flame temperature, the time of melting is materially shortened and therewith the time of heat. The time of testing is shortened for the same reason. The fuel consumption per ton of heat is lowered considerably. High steel temperature is easily and surely obtained. Due to quicker melting, less pig iron is needed, and the quicker a furnace charge is melted, the cleaner and better is the steel. The productive life of the roof and checkers, as well as the life of the furnace in operating hours, is lengthened considerably. Due to the absence of valve or flue maintenance expense and lower general furnace repairs, the cost of making steel is lower.

Operating Records and Economies Obtained

Improvements, like all other values, are relative. The actual savings resulting from the Isley Furnace Control depend upon the steel practice and local conditions. However, installations made show substantial gains over previous records in the same plant. A small foundry furnace, for instance, showed a gain with Isley Furnace Control over previous practice as follows:

SMALL ACID FURNACE COLD SCRAP AND IRON

	Previous Run on Stack	Best 11 wks. on Previous Run	1st-12 wks. on Isley Control	Saving
Avg. Bottom Time	4 41	1 29	1 25	
Avg. Melting Time	3 19	3 24	2 50	16.5%
Avg. Testing Time	1 35	1 46	1 38	
Avg. Time of Heat	4 54	5 10	4 28	14.7%
Avg. Tap to Tap	9 35	6 39	5 53	
Galls. of Oil per Ton	82.6	64.8	48.7	24.8%
Tons Prod. per Week	182.8	256.0	266.4	4%
Tons Prod. per Heat	9.9	9.9	9.4	
Tons Melted per Hour based on Melting Time	2.99	2.92	3.31	13.4%

A larger foundry furnace showed a very con-

sistent and uniform rate of production throughout the furnace run, although business conditions and requirements in the size of the heat were fluctuating more than endurable for favorable results. The fuel consumption per ton melted likewise remained practically the same, while the total furnace repairs were almost nil for the entire run. A comparison between the performance of this furnace under Isley Control and as a natural draft furnace is as follows:

plant. It may be stated that the furnace with which the comparison is made is also equipped with a blower for the air supply and is otherwise of excellent construction.

Underlying Reasons for Higher Economy

We have already discussed the value of preheated air. The higher the temperature of the air

ACID OPEN HEARTH FOUNDRY FURNACE

Started producing steel under Isley Control	28 September, 1927
Shut down for Rebuild	30 November, 1928
Total Furnace Repairs while operated with Isley Control	$481.05 material and labor
Time in operation on 9" roof previous to installation of Isley Control	25 weeks
Time in operation with same 9" roof operating with Isley Control	63 weeks
Total time of operation on 9" roof	88 weeks
Number of heats and tonnage produced on 9" roof previous to installation of Isley Control	454 heats and 12323.5 tons
Number of heats and tonnage produced on same 9" roof operating with Isley Control	1135 heats and 28761.2 tons
Total heats and tonnage made on 9" roof	1689 heats and 41084.7 tons

	Plain Carbon Steels		High Carbon Alloy Roll Steels	
	Isley Control	Previous Run	Isley Control	Previous Run
Number of Heats	602		533	
Average Melting Time	3.47 hrs.	4.31 hrs.	4.34 hrs.	5.16 hrs.
Average Testing Time	1.25 hrs.	1.20 hrs.	2.09 hrs.	1.44 hrs.
Average Time of Heat (charge to tap)	5.12 hrs.	5.51 hrs.	6.43 hrs.	7.00 hrs.
Saving in Melting Time with Isley System	.44 min. or 16.2%		.42 min. or 13.3%	
Oil per Ton on Melting Time	28.1	35.7	34.0	45.6
Oil per Ton on Time of Heat (charge to tap)	36.2	43.3	44.1	53.1
Saving in Oil per Ton on Melting Time with Isley System	7.6 galls. or 21.3%		11.6 galls. or 25.5%	
Saving in Oil per Ton on Time of Heat with Isley System	7.1 galls. or 16.4%		9.0 galls. or 17.0%	
Tons melted per hour based on Melting Time	6.85	6.10	5.42	4.68
Tons produced per hour based on Charge to Tap	4.98	4.71	3.68	3.51
Increased tons melted per hour on Melting Time	.75 tons or 12.3%		.74 tons or 15.8%	
Increased tons produced per hour on Charge to Tap	.27 tons or 5.7%		.17 tons or 4.8%	
Average tons per heat	25.9	27.5	24.7	24.6

An interesting observation was made in one acid open hearth ingot furnace, which has the following roof history:

Average life of last 7 runs on Natural Draft	249 heats
Life of 1st run on Isley Impeller Fan	340 heats
Life of 2nd run on Isley Impeller Fan	395 heats
Life of 3rd run on Isley Impeller Fan	388 heats
Life of 4th run on Isley Impeller Fan	361 heats
Life of 5th run on Isley Ejector System	529 heats
Life of 6th run on Isley Ejector System	670 heats

With certain recommendations which have been made in connection with this particular furnace, it is expected that the last record of roof life will be still further and materially improved.

Two large basic furnaces, which have been in operation for over a year, are reported as doing ten per cent better than the best furnace in the same

reaching the port end, the higher will be the flame temperature and the more perfect the combustion, which means that there will be more complete combustion with less excess air. With more perfect combustion there will be less secondary combustion in the checker chambers and flues, due to the absence of surplus combustible. This results in less destruction of checkers which fuse under the temperature strain of secondary combustion. The heat stays in the furnace—so to speak—instead of being produced beyond the furnace. There is a definite control of the air of combustion, as well as that of the draft. There are no cross drafts from leaky reversing valves and faulty water seals. There is a minimum weight of waste gases per B.T.U. of fuel and at the highest effective temperature for regeneration.

The regeneration is gradual from the cold end to the hot end, and on account of this it is more com-

plete. Where cold air is taken in into the main checkers through a valve located in their vicinity, there is a sudden and violent exchange of temperature which cannot be expected to be efficient, and while the main checkers of a natural draft furnace may actually be higher in temperature at the outgoing end due to secondary combustion, the entire checker mass, and especially the portion nearest to the uptakes, is of lower mean heat value, as well as lower average maximum temperature. In the Isley controlled furnace system, regeneration is continued almost to the point where the waste gases are discharged into the atmosphere.

Draft and Its Control

As is well known, the capacity of a chimney is limited by the temperature of the waste gases and by the weather. The chimney capacity is further checked on the one hand by larger volumes which must be taken care of at higher temperatures, and, on the other hand, by lower draft at lower temperatures. The maximum capacity of any chimney varies from about 660° F. flue gas temperature at 100° F. atmospheric temperature to about 375° F. flue gas temperature at 50° below zero atmospheric temperature. Any deviation of the flue gas temperature above or below the points of maximum efficiency, will rapidly decrease the capacity of the chimney in its function of removing waste gases from a furnace system.

In Open Hearth furnaces the induced draft system has been used only in connection with waste heat boiler installations, but as a means of furnace control the induced draft in combination with boilers is of limited value to the furnace, due to high draft resistance from many passages. The boiler performance, itself, is depending upon the weight and temperature of the waste gases, and the rate of evaporation must therefore fluctuate with the rise and fall of waste gas production during the metallurigcal process of making a heat of steel. There is a high fuel consumption during the melting down period, and actually none during the period of making bottom. Aside from the benefit that the furnace may obtain by the assistance of the induced draft fan, it seems to be wrong to correct a poor furnace system by the addition of more equipment in the form of waste heat boilers. It is like tying two strangers together and showing one of them up at the expense of the other. As we have already pointed out, with some fuels the economic value of waste heat boilers seems entirely out of the question. If it is a matter of insufficient draft, efforts should be made to correct this fault and if the regenerative system is not satisfactory, it should be corrected.

With the elimination of the waste heat boiler as a buffer against high temperatures reaching the induced draft fan, the most practical means of producing mechanical draft is by the ejector principle. This simple method is endowed with a flexibility of design and capacity which is particularly desirable in metallurgical furnace work. The capacity can be accurately chosen by keeping within the fundamental laws subject to which the ejector type stack is functioning. These laws are as follows:

1. The suction pressure or difference of pressure (draft) which is caused by the discharge of a fluid stream is proportional to the pressure of the fluid, i. e., the water column which corresponds to the velocity with which the fluid is discharged.
2. The suction pressure or difference of pressure is only dependent upon the ratio of the throat area to the nozzle area, and upon the ratio of the suction area to the nozzle area, but not upon the absolute sizes of these three areas.
3. The suction pressure diminishes with the growing ratio of suction area to nozzle area all the more, the smaller the ratio is of the throat area to the nozzle area, i. e., with the throat becoming relatively smaller.
4. For each definite ratio of suction area to nozzle area there is a correspondingly effective ratio of throat area to nozzle area, for which the expansion of the induced fluid and its quantity-flow are the greatest.

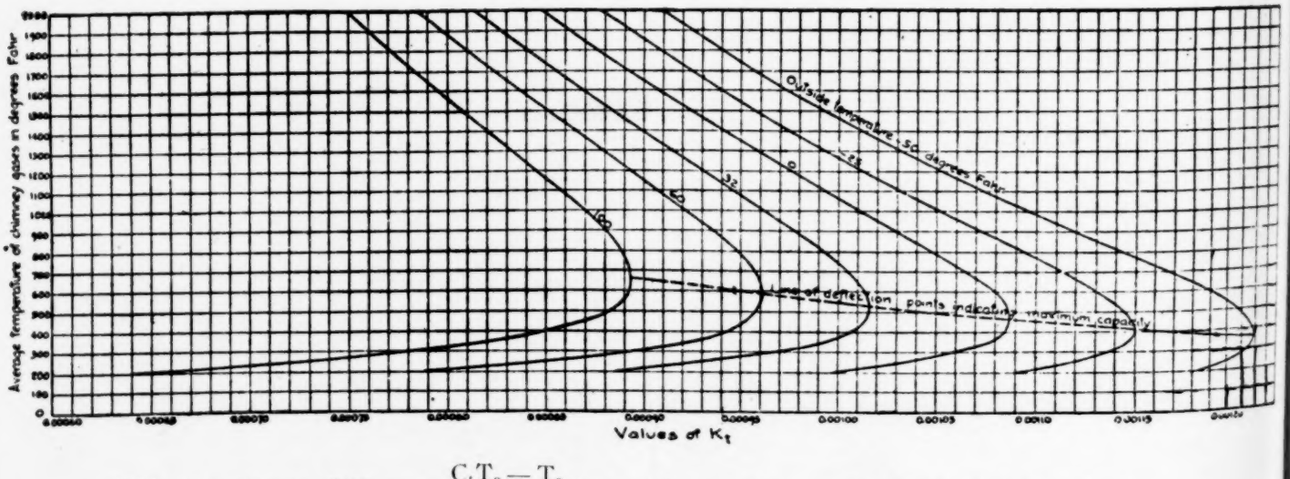

FIG. 11.—Curves of $K_t = \sqrt{\dfrac{C_t T_c - T_o}{T_o T_c^2}}$ in capacity equation together with line of deflection points indicating maximum capacity.
Based on $W_c = W_o = 0.08071$ or $C_t = 1.00$

5. With constant throat area and nozzle area the quantity of the induced fluid increases directly as the square of the pressure difference between the driving fluid and the outside atmosphere.
6. With constant nozzle area, throat area and constant pressure of the driving fluid, the quantity of the induced fluid increases with growing suction area, but finally reaches a maximum which is never surpassed no matter how great the suction area may be. Even with infinite suction area, i. e., when freely open to atmosphere, the quantity of the induced fluid is not greater than that corresponding to a suction area determined as the maximum.
7. With constant nozzle area, suction area, and constant pressure of the driving fluid, there is a certain throat area, for which the quantity of the induced fluid is the greatest. The most efficient throat area, however, is the smaller, the smaller the ratio of suction area to nozzle.
8. In discharging a fluid from a container, neglecting the influence of resistance upon the creation of discharge velocity, an amount of work is performed, which is equal to:
   a. The work absorbed by the fluid in keeping the pressure in the container constant increased by:
   b. The work liberated when the fluid undergoes a change in pressure from that in the container to the pressure ruling outside, and is finally decreased by:
   c. The work which must be performed by the fluid in order to combat the constant counter-pressure on the outside.
9. The induced fluid moves through the throat with the same velocity and under the same conditions of pressure as the driving fluid.
10. With constant ratio of the suction area to nozzle area and constant pressure of driving fluid there are always two values of the ratio of throat area to nozzle area, for which the same quantity of fluid is induced.

True to the laws above expressed, we find that in a typical Isley controlled furnace installation, the static pressures and drafts may be varied tremendously from the beginning of a furnace run to the end of the same, without materially increasing the requirements of the ejector fans and, at the same time, maintaining balanced draft in the hearth chamber and a uniform rate of melting and combustion.

As far as the power consumption of the ejector draft system is concerned, it may be viewed in comparison with the cost of operating a stack. It is said that a fan can be run for about 1/10 of the power represented by the waste heat required to command a good draft in a brick chimney ("London Engineer"). The actual power charge varies, of course, with local and furnace conditions, but should never be much higher than the equivalent of one gallon of fuel oil per ton of steel made.

This powerful draft apparatus can, nevertheless, be harassed to a large extent if moisture is permitted to enter the checkers or flues, due to the extra heat required from the waste gases to make super-heated steam out of moisture, and on account of the effect that this steam ballast has on the development of

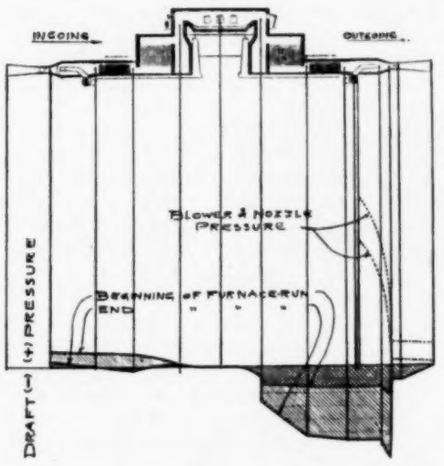

FIG. 12.

combustion. It is claimed that one pound of moisture is responsible for 2.2 pounds of additional flue gases. This means that the draft equipment will have to remove more than double the weight of flue gas as is represented by the net weight of moisture, which is permitted to enter the system.

Another disturbing, but often sadly neglected furnace disease, is air leakage through cracked checker chamber and flue walls. It is less difficult to destroy suction than it is to disturb pressure. Probably every furnace man can be brought to a realization of this fact by offering him a cigar which has a slight crack in the wrapper. Air leaks, wherever located, should conscientiously be stopped. This trouble can, of course, be minimized, or practically eliminated, by better furnace construction. Many furnace builders and steel companies are covering checker chamber side and end walls, as well as, in some cases, the flues, with steel plates. These should be extended several feet below the surrounding floor level, because cracks can develop there, as well as where they are in sight, but are not easily discovered. The peep holes should be treated with like appreciation of the bad effects of air leakage. They should be covered by a swinging slide and should never be permitted to remain open. The opening of the doors should be cut down to a minimum. The door frame and door construction should be of a type which will stand physical abuse as well as high temperature. The door sills, or foreplates should be kept clean.

Conclusions

From the observations made and the thoughts expressed, it may be deducted that the portions of a furnace system, which are outside of the seemingly most important hearth chamber construction, in reality are the most vital part of the plant, the most easily vulnerable and the most unintentionally miscreated. Experience with the Isley Furnace Control points to the probability that the selection of chamber dimensions, especially with reference to roof location, port end shape, slopes, etc., is far less delicate for satisfactory operation and economy than that of the checker and flue construction. By far the most beneficial contribution, however, seems to be the combination of positive air supply with a wide

range of adjustable draft. This combination is putting the furnace under the control of the furnace man as definitely as the accelerator and the foot brake subject the performance of the motor vehicle to the will of its operator.

While this novel apparatus has been applied so far to Open Hearth Furnaces and Soaking Pits only, it may be equally well incorporated into the air and waste gas systems of other types of furnaces where fuel economy and control of furnace performances are of importance, by suitable modifications.

This limit of ultimate economy to be obtained is depending solely upon the excellence of furnace construction and upon the intelligent use of the draft, pressure, temperature and fuel indicating devices. The arrangement will permit of the operation of a furnace outfit which it is impossible to operate with any stack.

In recent years, it has been pointed out, especially by European investigators, that for use of Coke Oven Gas and of mixtures of Coke Oven Gas and Blast Furnace Gas in the Open Hearth Furnace, the fuel should be preheated to a very high degree of temperature in order to obtain luminosity of flame. The radiating quality of such a flame increases the rate of heat transfer to the steel charge and bath, and the incidental visibility aids the furnace man to judge the conditions of the combustion performance. The difficulty pointed out in this respect is the correct proportioning of the flue gases and air for combustion through the gas and air regenerators respectively, which must first be carefully calculated under more or less assumed conditions and then corrected during operation by the manipulation of dampers. The Isley Furnace Control offers here an excellent and simple means for securing the best possible allocation of the flue gases and the returning air to the two sets of regenerator circuits, by connecting them separately to ejector tubes and fans which can be regulated instantly and at will for the best operating results which may be expected from the fuel chosen or received. Such regulation is highly desirable on account of the variation in quality of the fuel which is not easily maintained at constant value if the interests of the fuel producer are to be honored with reasonable consideration.

An interesting experience with Soaking Pits operated under Isley Control may indicate the validity of the foregoing discussion on the importance of preheating the air of combustion. The pit furnaces of the plant, in which this experiment was made, are fired with a mixture of Coke Oven Gas and Blast Furnace Gas having an average heating value of 240 B.T.U. per standard cu. ft. The Isley controlled pits operated about 37% faster with this mixed gas than the natural draft pits, yet there was no difficulty of obtaining even temperature of the ingots. To give the pit charge a few minutes soaking with the fuel and air cut off, the Controla pparatus is shut down and the pit holes are sealed. The question had been raised whether cold Blast Furnace Gas could be used with the air alone preheated and it was finally decided to try it. A separate gas pipe was installed to the Isley Controlled Pits and two holes were charged with cold ingots at the same time charging two holes of another furnace, running on 240 B.T.U. mixed gas, with cold ingots of the same dimensions and weight. There were three ingots 25″x30″x84″ weighing 14,000 lbs. a piece in each hole. The Isley controlled Pit Furnace heated these ingots in 8 hours and 32 minutes to rolling temperature without any transferring. This was twenty minutes' less time than required in the furnace fired with 240 B.T.U. mixed gas under natural draft. Thus a wider field of utility for Blast Furnace Gas may be put in use by careful attention to the value of highly preheated air. It is but logical to consider the lower grades of fuels for heating furnaces and the richer fuels, with which high flame temperatures can be easily obtained, for melting furnaces. When this is accomplished without resorting to the regeneration of the fuel, the entire furnace system becomes considerably simplified.

Discussion

Kenneth C. McCutcheon*: Mr. Chairman and Gentlemen: I must say that I did not read Mr. Merkt's very excellent paper in advance and therefore, I am able to discuss only a few points intelligently. There are a few remarks I am able to make and one is that the control works satisfactorily.

We have two furnaces operating at over 100-ton capacity. He made remarks on greater production and improved fuel consumption which are part of a report I made, of which I haven't the details and cannot quote, except to say that the statements made are fairly accurate. I reported 8.3% longer life, 8.5% less fuel, and 12.2% faster production than the best furnace which he lumped at 10%. In going along I made a few notes that it is probably worthwhile bringing to you. One is that with the Isley draft control—and I think Mr. Merkt is right in bringing to your attention the fact that it is a draft control and not a furnace—makes possible a very, very good control and balance, as far as the combustion condition is concerned, that it is within the hands of the operator, and that better arrangement and regulation is possible than heretofore.

Some of you would probably want to know something about the mechanical delays connected with the equipment. We have probably had a total of, I would say, four hours on these two furnaces in over a year's operation, and I would attribute a large part of it to lack of preparation or poor preparation to take care of it. We had the failure of an armature and we weren't mechanically equipped to pick up a big armature and put it in place, and the furnace was run four hours on one end while the change was being made. We have since installed a better system and we don't' expect any delays from that type of mechanical or electric trouble.

With respect to the draft, a perfectly cold furnace, as a furnace man would say, "will pull your

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hat in the door," 'so you have a wonderful chance of starting up a cold furnace. You are not dependent on natural draft conditions.

Another point of interest probably is power consumption. I will bear out his statement in that on the Isley furnace we have used from 5 to 6 kw per ton. He said a gallon of oil and that is very close. We are operating all the other furnaces with pusher fans and those use between 2½ and 3½ kw. per ton.

As to the installation of the Isley furnace in a plant, I think that you can probably realize to the utmost the full benefits in a small plant, that is, one, two, three, or four furnaces. I might put it differently, that the conditions surrounding the plant will allow you to realize the full benefits or not; in other words, how many furnaces in the line, class of charging equipment you are using, class of raw materials you are using, and so forth. All those enter in, but in a foundry plant I would say the full possibilities can be realized and I think they are great.

There are several things I should like to suggest to Mr. Merkt: That in his thorough study of temperature balance in the furnace he pay particular attention to the fact that the recording devices now in use give us a temperature reading which must be understood to be interpreted correctly.

Run a furnace in one direction and read the temperatures recorded by a thermo couple in the outgoing end and, as long as fuel is being burned, the temperature read will continually increase. Readings from a thermo couple similarly placed, on the ingoing end show that the temperature indicated will decrease. In the Isley controlled furnace you have your air starting at the remotest point in the system and traveling from there on to the furnace, and your temperatures recorded at that remote point must of necessity be controlled more directly by atmospheric temperatures than any other. It is well to bear that in mind in studying furnace balance based on the temperature recording device that you have.

I would question one statement he made, i. e., that the design of flues and regenerators was very much more important than the lines of the furnace chamber. I would say Mr. Merkt has had the greatest amount of experience and the greatest success so far with fuel oil furnaces and there your flame control and direction is simple. In other gaseous fuels the lines of the furnace enter into it and play a large part in the control of combustion and furnace life.

I agree with him thoroughly that there is a great deal of attention to be paid to the design of regenerators and flues, but they occupy their place, and it is not a predominant one.

I want to say in closing my remarks that I enjoyed the paper very much and think it has gone into the fuel and combustion end of our game pretty thoroughly and I certainly will take great pleasure in studying his report carefully when it appears in the Iron and Steel Engineer.

H. C. Siebert†: We have an installation of a soaking pit. Some observations have been made on it, but I don't believe they are complete enough to give any definite data. I can only say it is working all right. We expected it to work satisfactorily. It was redesigned, and rebuilt and we expect good results from it. I was very much interested to hear Mr. Merkt's paper. He pointed out the advantages of an Isley compared to a natural draft furnace and made comparisons in heats, but I missed the statement of the all-important factor and that is the heat consumption per ton. I think it would be very interesting to have these figures given.

W. B. Chapman*: Mr. Isley's work is in line with the general trend toward getting better control of all types of furnaces including regenerative, recuperative and even boiler furnaces by means of artificial draft controlled automatically and accurately. Super capacity can usually be obtained with automatic pressure and draft control and usually cannot be obtained without it.

F. E. Leahy†: I have had the opportunity of seeing a number of Isley Open Hearth Furnaces in operation that were giving very satisfactory results. In the remarks of Mr. Merkt he intimated that the advantage of the Isley furnace would mean the elimination of the waste heat boiler for use on Open Hearth furnaces. I am inclined to question that statement, as I believe wherever it is desirable to use steam it will always be economical to recover the waste heat from an Open Hearth furnace in a waste heat boiler. This of course will depend on local conditions, and most of the disappointments obtained from waste heat boilers can be traced to poor flue construction between the Open Hearth furnace and the waste heat boiler.

The Isley furnace admirably provides positive control of the air and draft, which should make it possible to maintain uniform Open Hearth furnace operation for the campaign of the furnace. I have always been in favor of such control, whether automatic or semi-automatic, with the use of instruments that will provide the information necessary to main tain the correct operation. The more facts we obtain about a furnace the easier it is to correct the troubles.

One of the most prominent defects in the standard Open Hearth furnace has been the strangulation of the furnace through small valves and outgoing flues, in many cases much too small for the quantity of outgoing gases. The Isley furnaces that I have had the opportunity of seeing were not subject to this trouble, as they had ample flue sizes to obtain the air necessary and draft without excessive pressure losses. In the case of many standard furnaces the addition of a pusher blower has solved the difficulty of securing air, and where the fan on the waste heat boiler is capable of supplying all the draft necessary, the combination of pusher fan and draft fan provides the proper requisites for good operation.

It is appreciated in many plants that to reduce the time of heats it is necessary to get a quick meltdown, as the amount of fuel to be burned at this period compared to the amount of fuel burned at the refining period is appreciably higher. To meet this condition it is rather difficult on the standard natural draft furnace, unless they are equipped with pusher fans, particularly when a gaseous fuel is

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*Chapman-Stein Company, Mt. Vernon, Ohio.

†Combustion Engr., Youngstown Sheet & Tube Co., Youngstown, Ohio.

used. When using a liquid fuel, with both chambers preheating the air, it is not so difficult to meet this condition, and it is the flexibility obtained from Isley control to meet the above conditions that make it particularly attractive.

The first step, it would seem to me, in the general practice would be the application of such instruments to the furnace as will enable the operators to determine how their furnaces are limited, and from this point it is usually possible to determine what are the economic desirable changes.

I recently had the opportunity to see one Open Hearth furnace that was completely equipped with CO_2 recorders, draft gauges, flow meters, and pyrometers, which enabled the operator to accurately determine the conditions surrounding the operation of the furnace at all times, and the results obtained from this practice were excellent.

J. L. Hott‡: I have been very much interested in this paper and the various furnace controls. I agree with Mr. Leahy in that I question Mr. Merkt's statement about the elimination of waste heat boilers. It seems that we do not distinguish between fuels such as oil, coke gas, natural gas and producer gas. In producer gas about 40 per cent of the necessary air to burn the coal goes in through the producer and about 60 per cent through the open hearth furnace checkers. We are all familiar with that. If it were possible to make a furnace which would regenerate the air up to the same temperature at which the flue gas comes out of the furnace there would still be considerable heat left over, it seems.

Prof. Trinks in his book, "Industrial Furnaces," shows curves of heat content of flue gas and air at various preheat, etc. These curves are very thoroughly worked out and are easy to understand. The heat curves for the flue gas at various temperatures and the heat curves for the air at the same temperatures are very far apart for producer gas. Oil and coke gas curves lie very closely together. Theoretically, this would prove that neglecting any gas evolved from the bath, if it were possible to build a furnace with sufficient regenerators and probably metal recuperators or something on that order, on the lower temperature end of it—which would probably cut down the expense—the incoming air temperature could be brought almost up to the temperature of the outgoing air. There may be a difference of two or three hundred degrees, I am not sure, but the air volume is sufficient to absorb most of the flue gas heat.

In the case of producer gas, about 40 per cent of the air goes through the producer and it is impossible to heat that air. It requires the same amount of air, I believe, to burn a pound of coal, whether burned in a producer cycle or direct. The steam goes through the cycle and goes out as steam, but at a higher temperature—therefore, it would appear possible to eliminate the waste heat boilers on fuels such as oil, coke-gas, natural gas (which I believe will not be available much longer) and probably the mixture of blast furnace and coke gas. However, so long as it is possible to preheat only 60% of the combustion air in the producer system, the waste heat boiler will probably hold its own.

‡Combustion Engr., Wickwire Spencer Steel Co., Buffalo, New York.

Should a system be worked out whereby it would be possible to successfully use powdered coal in the furnace, all the combustion air could be preheated.

I agree with Mr. Leahy that more control is needed. I think every furnace should be equipped with a fan for inlet air and that the air used should be metered. Measuring by weight, about fifteen times as much air is used as gas. Air control is equally important in the combustion reaction—too much causes scaling, etc., in the case of reheating furnaces. Too little air results in wasted fuel. We have heard many heaters complain because they do not have positive control of the air. If they get good heating on their pits or furnaces they cannot duplicate it always due to improper air valve regulation, etc. This condition could be remedied by the installation of an inexpensive low pressure fan and air meters. There are a number of good meters on the market, for air especially when one has a couple of inches of water pressure to work with. Some years ago the Jones & Laughlin plant went to considerable expense to install recording pyrometers in the Open Hearth checker chambers, CO_2 machines and several recording gauges on each furnace, and they learned quite a number of interesting things about Open Hearth Furnace characteristics. In this connection, however, a word of warning is in order: Pyrometers placed directly in an Open Hearth Furnace checker roof are an expensive proposition. Even a platinum couple protected by quartz and refractory tubes will not stand up long under the severe service. Pyrometers in the flues have proven very successful.

Future Open Hearth Furnaces will probably be supplied with fans and definite control for fuel and air.

J. S. Green*: I am not a furnace man and consequently my view of this is from a different standpoint. How much heat recovery of the waste heat is possible? This plan, as I see it is to throw the heat away. That is contrary to the modern trend of progress and the best means of recovery has been through the waste heat boiler. There are several satisfactory installations. The only point that I can see is the increase of production of this system over the natural draft or induced draft system of waste heat to the boiler. If there is enough to overcome the benefits of the recovery of waste heat then this is the best proposition, but if it is possible to recover anywhere the same percentage of waste heat due to a little change in fan design or something that will give the Isley control the same results, but give the recovery of the waste heat beyond this fan, why then I think there is a field for recovery beyond the fan in this Isley proposition.

G. A. Merkt: Mr. McCutcheon disagreed with a statement that the checker chamber and flue design was more important than the hearth chamber lines. I didn't exactly say that. I said it was far less delicate to make your selection in the roof line and port end shapes. Of course, in the first place, in order to make steel you have to have a hearth chamber; but we found by observation with the Isley Control that with the surplus draft available and also with means of supplying air under pressure, it isn't very difficult to direct the air. Take the oil-fired, natural draft furnace—some of them have

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straight roofs. You can pull that flame across the hearth with a sufficient amount of vacuum on one end and a little pressure of air on the other end; the flame will go down all right. Why does the flame in the hearth travel to the back wall? It is because air leaks in along the front wall through the doors and that pushes it. The flame apparently has a tendency to move away from the source of air as it develops volume.

So, if you let the air roll in over the top of your fuel, you direct the flame down. What little direction of air there is has practically no effect on the flame by the time you get to the end of the port. The flame stays on the bottom as long as you have a blanket of air on top. It is bound to do that. At least, those are observations you can make in letting air in somewhere to see what happens to the flame. You can see it in an ordinary heating furnace. If you the air under the gas, you push the flame up to the roof. If you put it in above, you push down towards the hearth. But if you have insufficient draft (not enough to pull on the other end) then gradually the flame will go up to the roof, naturally.

However, I would not be taken too seriously about that. I merely suggest that some studies should be made along this line. We have some furnaces in which the uptake is simply a big hole through which the air can come up and roll over the breast, and it works fine. It works both ways. Sometimes you design the furnace port having nothing in mind but the getting of the fuel in and you neglect getting the gases of combustion out, which is just as important.

There are indications along these lines in existing furnaces, and I suggest you combustion engineers who have the opportunity to make measurements and tests would find out something about it.

Mr. Seibert brought up a question as to the amount of heat consumed. That means the B.t.u.s per ton of product, I suppose. That is problematical, what have you got? You have one thing in one furnace and something else in another furnace. What is your practice? What kind of steel do you make? What kind of charge do you use, and there are other things. It is simply this much—that wherever you use furnace control such as the Isley, you will improve the B.t.u. consumption per ton of product.

We have very little information as to what it is for different kinds of steel practice. We only know it is anywhere from 10 to 25 per cent better, depending on how good it was before. This control apparatus will make a bad furnace a good one and a good furnace a better one.

H. C. Siebert: In that connection you made a comparison on some small foundry furnaces. You made a comparison in time of heat and reduction of melting period. Now let's have the fuel consumption.

G. A. Merkt: If I give you the oil figures, will you translate them into B.t.u.s? For instance, for an entire run on a small furnace, a 40-ton foundry furnace, for plain carbon steels, the oil consumption per ton on melting time was 28.1 gallons. The oil used for refining was 7.6 gallons per ton, so that added to the other, this would make 35.7 gallons of oil per ton of steel for the entire heat.

Now in this furnace the melting time is about 64 or 65 per cent of the total time of the heat. In other words, there is about 35 per cent of refining time required in order to get the analysis which they want for casting work.

On high carbon alloy Roll steel it is a little higher. The consumption of fuel was 34 gallons per ton on melting time. That is the average of the run, and it took 10.1 gallons more to finish the heat, or a total of 44.1 gallons per ton charge to tap.

Previous to that, this was 45.6 + 7.5, which made 53.1 against 44.1 or a saving of 25 per cent.

Does that answer your question, at least partially?

H. C. Seibert: I believe that answers the question in part, but I believe a lot of the boys here are very much interested in that question. It is a very important one and I wasn't staggered by the figures at all, because we have natural draft furnaces which have an oil rate of 32 gallons per ton and tests made twenty years ago in one of the big plants in the Pittsburgh District on natural draft furnaces burning producer gas gave records which we have of 3,500,000 B.t.u.'s without any controls except a few engineers hanging around.

G. A. Merkt: I venture to say that if you had a control system and a tight system, you would still improve those conditions. You are bound to; it is impossible not to improve them.

Now, Mr. Leahy, my statement about waste heat boilers—I didn't claim that there was no place for waste heat boilers. I am confronting engineers and I have to be careful about it, especially before mechanical engineers, for with them the boiler is paramount. Most engineering studies have been made in the boiler and boiler practice and all combustion considerations were always compared with the practice used in boiler furnaces. However, these considerations didn't always apply to metallurgical furnaces. But I did say where you use fuels which require so much air, that, at least theoretically, there is hardly enough waste heat available to preheat the air properly, there is no use of making the furnace run rotten in order to have waste heat. In order to make one show up good, you make the other show up bad. It would be better to use the money and put it into a modern boiler plant. Great progress has been made in modern boiler plant design. You can make steam cheaper in the boiler than in the open hearth furnace. But where you have waste gas, which comes from poor fuel, such as producer gas, that is another story, according to best theory. Whether practically this is economical, we are not convinced yet, because we don't think you have everywhere this excellent preheat that we are preaching.

There is an installation being made on a producer-gas-fired furnace in which it will be attempted to burn producer gas without regeneration, and we will soon learn whether it is worthwhile doing it. We believe it is.

The performance of this heat exchange is a complicated one and there are all kinds of things that influence it. One of the reasons why waste heat boilers can evaporate so much steam is because there

is a lot of weight of waste gas going out. Where is it coming from? Ballast! That is again expressed in fuel used per ton of steel; otherwise, the boiler would not be doing as well. Another proposition, of course, is this: where you already have a waste heat boiler installation, it is almost impossible to show your stockholders that you should throw out the equipment, take some new money for a boiler plant, and when you get through with it, have only a little better or about the same as you had before. Where you already have a waste heat boiler installation, especially in connection with producer gas or mixed gas, it is usually out of the question to change. That waste heat boiler plant has got to stay. It is the only logical thing. The only question is, how efficiently you should operate it, whether the furnace or the boiler plant. It depends on which you need more, steel or steam.

Mr. Green seemed to have missed the point on the Isley Control about heat recovery. This thing is not done at the expense of heat recovery, but just because there is heat recovery. The idea is to recover as much of the heat as possible so as to keep it in the furnace, so to speak, and if that is done completely of course, there is nothing left for a waste heat boiler, except where we have producer gas or mixed gas, in which the ingoing air, as Mr. Hott said, returns 40 per cent, or something like that. Where we have rich fuels, it should be thought over very carefully, especially in a new installation, whether we want to operate waste heat boilers in connection with an open hearth plant.

*Certain Principles in the Extended Utilization of Blast Furnace Gas**

By OWEN R. RICE†

As in any other not fully surveyed field, the extended utilization of blast furnace gas beyond the well-trodden area of steam and stoves, is staked off by some quite definite principles which can be reviewed with benefit.

Most of the important heating units in a steel plant are adaptable to the application of blast furnace gas: hot blast stoves, by-product coke ovens, steel heating furnaces, boilers. Taking these several heating units in reverse order, let us consider the principles that attain to each, leading up to a ratio between the value of blast furnace gas as fuel in each case, and the cost involved in rendering it suitable for such use.

Under Boilers

In steam boiler practice, blast furnace gas is an ideal fuel when the gas is properly conditioned and when the boiler setting is arranged with sufficient effective furnace volume. Economizers and air preheaters show a better return on the investment in firing blast furnace gas than with the same boiler so equipped firing coal, because the flame temperatures are lower in the case of gas-fired boilers. The ratio of heat released by direct radiation in a coal-fired furnace to that in a gas-fired furnace, is about 2.4 to 1 when using cold combustion air in both cases. By preheating air to 400 deg. in the case of gas firing, the ratio drops to 1.4 to 1. The use of preheated air in coal firing calls for additional water wall surface, while no such addition is required when using preheated air with blast furnace gas. Water or air-cooled side walls are not desirable in straight blast furnace gas-fired boilers, especially if operation is occasionally at low loads, since the cooling effect of such walls tends to arrest combustion.

Refractory losses, due to furnace temperatures in blast furnace gas firing, are nil and the temperatures should be kept as high as possible, provided the gas is suitably cleaned. It should be physically dry, that is, free from entrained moisture, and in such condition should have its dust content reduced to .2 grains per cu. ft. This dust burden in dry gas has no detrimental effect on boiler operation. Such conditioning may be accomplished by wet-washing the gas in a static tower, and subsequently pre-heating it well above the dewpoint, waste stack gases at around 400 deg. F. being satisfactorily used for the purpose. Gas which has been wet-washed in a static tower and then preheated to a super-dewpoint temperature of perhaps 110 deg., sustains a sensible heat loss of 1.5 per cent referred to untreated, raw blast furnace gas reaching the boiler at, say, 250 deg. But the reduction in aqueous vapor that occurs from the primary cooling in the washer to perhaps 85 deg., effects a betterment in flame temperature by about 130 deg. (5½ per cent), an item which in boiler practice outweighs the small thermal loss.

Boilers using gas thus conditioned have maintained continuous operation at 78 to 80 per cent efficiency for over two years, uninterrupted by need for scaling tubes externally or repairing slagged furnace walls. The absence of the sludge nuisance in mains and burners is most noteworthy.

It is sometimes a plant expedient to send wet-washed, non-preheated gas to boilers. This is the case where gas cleaning for other departments must be of considerable intensity, as hereinafter discussed and is contingent upon a preponderance of the total gas output diverted to uses other than boilers. In such event, it is apt to be more economically sound to provide sufficient capacity in the gas cleaning equipment used for the major portion of the gas, so as to accommodate also the gas intended for boilers, rather than to involve a separate conditioning plant of an entirely different nature for the boiler gas

*Presented before Chicago District Section, A. I. & S. E. E., March 6, 1929.

†Metallurgical Engineer, Freyn Engineering Co., Chicago, Ill.

	Conventional Stoves	Advanced Stoves
Number per Blast Furnaces	4	3
Efficiency	70%	82%
Gas per min. (1000 ton pig/day)	21,000 c.f.m.	17,500 c.f.m
Per cent of Total Net Gas Produced	25%	21%
Gas saved by advanced stoves	----	3500 c.f.m 45,000,000 B.t.u./day
Value of Gas Saved by Advanced Stoves	Maximum—	$35,000/year
	Minimum—	$21,000/year
	Assumed Average—	$25,000/year
Cost Checker Linings	$85,000	$125,000
Fixed charged (11%)	$9,300	$14,000
Debit a/c Advanced Stoves (yr.)	----	$4,700
Net Profit a/c Advanced Stoves (yr.).		
(a) Discarding Serviceable Linings	----	$11,000 (8.8% on investment)
(b) Renewal of Unserviceable Linings	----	$20,000 (50% on investment)

FIG. 1
EVALUATION OF STOVE LININGS

alone. With wet-washed, non-preheated gas, dust content should not exceed .04 grains per cu. ft.

Boiler coal is fired at perhaps the average steel plant for about 13 cents per million B.t.u.s. Conditioning of the gas for boiler costs, in fixed charges and operating expenses, between 2 and 4 cents per million B.t.u.s. This is a ratio of fuel value in blast furnace gas to conditioning cost of 4 to 1. As will be shown, blast furnace gas carries a higher monetary value in other lines over its use as boiler fuel. There are exceptions where electric power developed with steel plant steam replaces costly purchased power, in which case a higher earning value as boiler fuel may obtain to blast furnace gas.

In Steel Heating Furnaces

Blast furnace gas is practicable fuel on suitably designed heating furnaces. Roof design must be such that the flame "wipes" both the steel and the roof, as in the Siemens furnace. Heats of 20 to 30 tons per hour of 8x8 to 4x4 blooms and billets are handled in a 70 ft. furnace at 6 per cent fuel use and 2300 deg. temperature of steel.

With 2100 to 2300 deg. as the requisite steel discharge temperature in heating practice, and a theoretical flame temperature of about 2200 deg. for cold blast furnace gas and air, regeneration is obviously necessary, and is provided in such heating furnaces as the Siemens design. Flame temperatures from preheated blast furnace gas and air are as follows:

	Flame Temperatures deg. F.
Gas and air preheated to 1500 deg. F.	3350
Gas and air preheated to 750 deg. F.	2900
Gas and air preheated to 375 deg. F.	2650

The flame temperatures secured with fuel heretofore commonly used, coke oven and producer gas, are 3380 deg. and 3344 deg. respectively. Hence, blast furnace gas, if highly regenerated, has a good thermal lead.

Mixtures of coke oven and blast furnace gas may be used with or without regeneration. Theoretical flame temperatures of a mixture by volume of one-third coke oven gas and two-thirds blast furnace gas at several temperatures of regeneration are:

	Flame Temperatures, deg. F. (25% excess air assumed)
Cold gas, cold air	2620
Cold gas, air at 1000 deg.	3060
Cold gas, air at 1500 deg.	3310
Gas and air at 1000 deg.	3240
Gas and air at 1500 deg.	3690

When blast furnace gas is thus extended to the stel plant, it should be metered for accounting purposes. If it is mixed with coke oven gas, it must pass through some form of proportioning mechanism. Usually the extent of conducting mains is considerable. To avoid fouling mains or mechanism, the gas must be cleaned, and the dust content should not exceed 0.04 grains per cu. ft. The gas should also be practically dry.

Steel plant producer gas is made, from coal at $5 per ton as gasified, at a cost of 21 cents per million B.t.u.s. (at 23,000,000 B.t.u. in producer gas from a ton of coal), and blast furnace gas can replace it on a B.t.u per-ingot-production parity. Appropriate cleaning of blast furnace gas to 0.04 grains dust and 0.2 grains entrained moisture costs, in fixed charges and operaing expense, 4 cents per million B.t.u.s., a ratio of fuel value to conditioning cost of 5 to 1.

Under By-product Coke Ovens

If high regeneration temperatures are used on both gas and air, blast furnace gas will develop in the flues of coke ovens the same heat head over

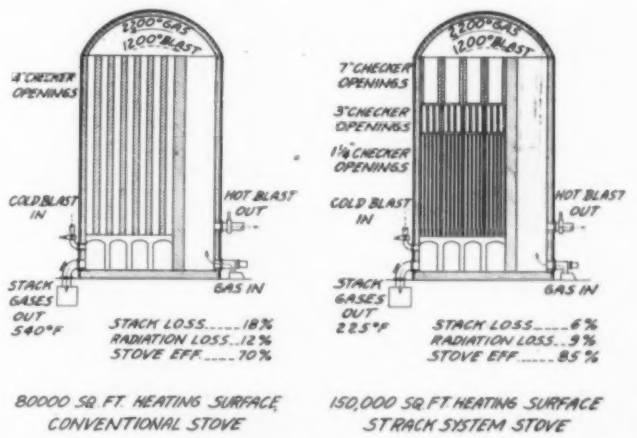

FIG. 2—Diagramatic Comparison of Conventional and Advanced Design of Hot Blast Stoves.

oven wall temperature and pushing temperature of coke, as cold coke oven gas and air at low preheat-conventional practice. If more moderate temperatures of regeneration are used, one may expect that 100 B.t.u.s in blast furnace gas will be required to replace 90 B.t.u.s in coke oven gas. Blast furnace gas, properly applied, appears to be adapted to the attainment of a more uniformly good quality of coke than with coke oven gas itself.

On account of the inaccessibility of flues and checkers, blast furnace gas for coke oven underfiring must be cleaned to not exceeding 0.01 grains dust per cu. ft. This cleanliness is also essential because of the high temperatures of combustion and regeneration obtaining, which would lead to brick slagging if dust were present in quantity.

Coke oven gas replaced in coke oven service by blast furnace gas, may in turn be employed to replace producer gas in mill furnaces. The credit reverting to the blast furnace gas is not apt to be as high as if the furnace gas were itself used in the mill furnaces. This is because, as above stated, 100 B.t.u.s in furnace gas may be required to replace 90 B.t.u.s in coke gas in coke ovens. The replacement value of blast furnace gas is therefore 90 per cent of the 21 cents indicated in a preivous paragraph, or 19 cents per million B.t.u.s.

However, coke oven gas has potentialities of considerably greater value than as a substitute for producer coal. As domestic or industrial gas, it may perhaps be marketed at 22 cents per thousand cu. ft. If such sales possibilities exist, it is worth 44 cents per million B.t.u.s, (equivalent to a coal value of $11 per ton). The blast furnace gas which releases it from coke oven duty, carries a potential value therefore of 90 per cent of 44, or 40 cents per million B.t.u.s.

The cost of cleaning blast furnace gas to 0.01 grains dust content is approximately 5 cents per million B.t.u.s. Here is a ratio, fuel value to conditioning cost, of 8 to 1.

Hot blast stoves:

One use to which blast furnace gas seems to be unavoidably committed is in the heating of the wind to the blast furnace. Substitution of other means is thus far impracticable, and to dispense with hot blast would be economically impossible.

Blast furnace gas is particularly appropriate to stove use because the moderate flame temperature

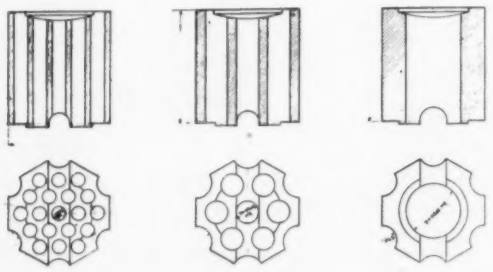

FIG. 3—Brick Tiles for Strack System Hot Blast Stoves.

imposes no undue stress upon the brickwork which must serve continuously without repair for four or five years, and without major replacement for twelve or fifteen years. Also the prevailing limit of blast heat requirements at about 1700 deg. permits of an average temperature potential between gas and brick of about 1300 deg. and between brick and blast of 875 deg. High regeneration of fuel gas and combustion air are neither required nor advisable.

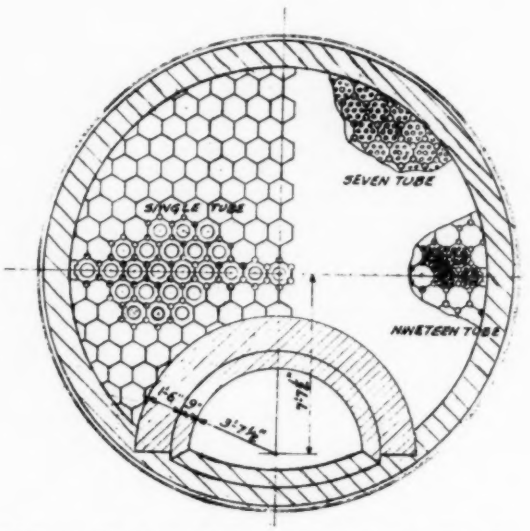

FIG. 4—Horizontal Section Through Strack System Hot Blast Stove.

The impossibility of dispensing with heated blast becomes obvious when one considers that hot blast saves one third of the coke charged to the blast furnace, i. e., 1100 deg. blast temperature permits of a coke rate of 1900 lbs. per ton of pig, whereas with cold blast the coke requirement would be 3000 lbs. Pig iron production rate per blast furnace stack would fall off about in direct proportion to increased coke rate, with consequent higher operating cost above raw materials. With coke at $4 per net ton, and existing "cost above" at $2 per ton pig iron, blast furnace gas used in stoves is worth to the furnace operation not less than 90 cents per million B.t.u.s.

The cost of cleaning blast furnace gas for stoves depends upon the type of stoves employed. For stoves of current designs, with large, continuous checkers, the gas may be cleaned—as in boiler practice—to 0.20 grains dust per cu. ft., and moderately preheated to above the dewpoint; or it may be wet-washed to not over 0.04 grains dust content. If stoves of advanced design and high efficiency are used, the cleaning must be more intensive, the allowable dust content being not over 0.01 grains per cu. ft. The cost of cleaning will be from 2 to 5 cents per million B.t.u.s, depending upon the method required. We find therefore a ratio between fuel value and conditioning cost for gas used in blast furnace stoves of between 18 and 45 to 1, the highest of any of the uses discussed.

Money spent in conditioning blast furnace gas for stove use carries the highest return because the gas itself is employed to such favorable advantage in operation of the blast furnace.

While this is ample reason for favoring the proper conditioning of gas to stoves, there is no logic in utilizing for stoves more gas than is essential to the adequate heating of the blast. In fact, economy at stoves is the only means within the province of the blast furnace operator, whereby he can enhance the credit for surplus gas dispensed to such other uses as were previously discussed: boilers, heating furnaces and coke ovens.

Recent improvements in design of hot blast stoves along lines of sound principles of heat transfer have raised the practicable efficiency of stoves from the

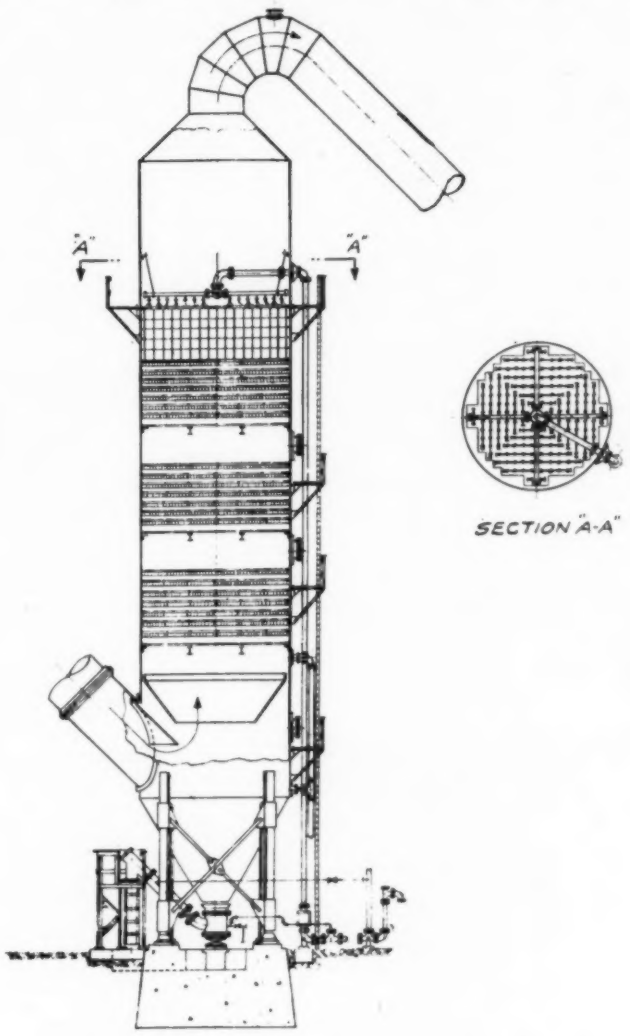

FIG. 5—Static Tower Washer or Pre-Cooler.

prevailing average of 70 per cent to an entirely practicable figure of 82 per cent. For a furnace producing 1,000 tons pig iron per day, 21,000 cu. ft. of gas per minute are required to heat the blast to 1200 deg. F. with stoves operating at 70 per cent efficiency. This is 25 per cent of the net available gas produced by the furnace. With stove efficiency raised to 82 per cent, the gas consumption will be

FIG. 6—Heat Exchanger.

reduced to 17,500 c.f.m., or 21 per cent of the make, a saving of 4 per cent of the make, or 3500 c.f.m. This represents an extra diversion of 465 million

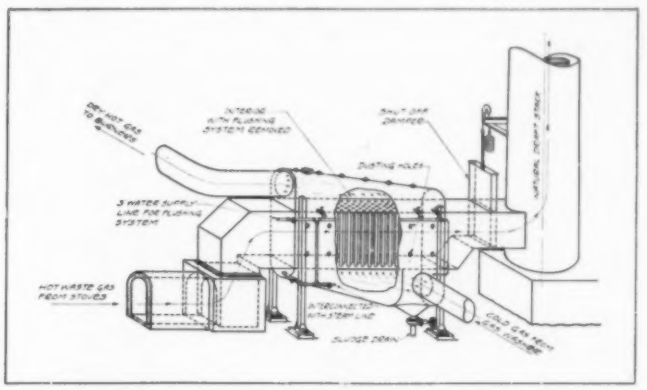

FIG. 7—Diagramtic View—Heat Exchanger.

B.t.u.s per day to other uses. Depending upon its disposition, it will carry value of between $60 and $100 per day, or between $21,000 and $35,000 per year.

Whether or not a saving of this degree justifies the expenditure included in the more efficient—but at the same time more costly—stoves, is determinable. (See Fig. 1). Where four stoves of conventional design are required, it suffices to have but three of the high efficiency type. The cost of four conventional type checker linings is $85,000. The carrying charges at 11 per cent are $9,300 per year. The cost of three highly efficient linings is $125,000; carrying charges $14,000 per year.

If good existing stove linings are to be replaced, the credit accruing to the gas saved must carry the expense of the new linings. If, on the other hand, the stove linings are old and deteriorated and require renewal in any event, then the gas saving carries only the $4,700 difference in the expense of the two expedients.

It is shown above that the gas savings are worth

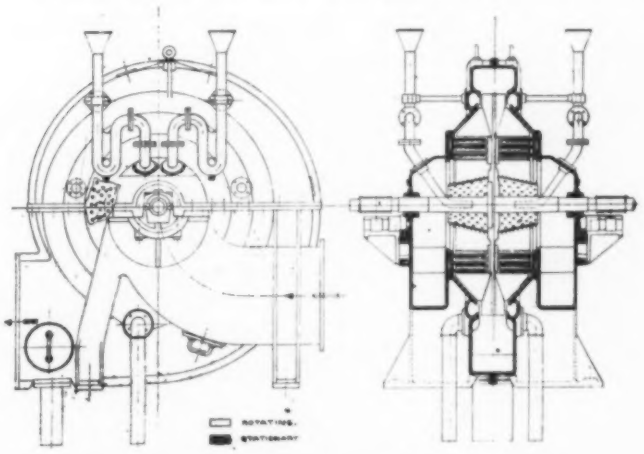

FIG. 8—Theisen Disintegrator Gas Scrubber.

between $21,000 and $35,000 a year. At an average value of perhaps $25,000, the saving in gas pays, on the basis of discarding serviceable linings, the $14,000 fixed charges, plus $11,000 (8.8 per cent) net profit on the investment. On the basis of required renewal of linings, the profit—after fixed charges—is $20,000, or 50 per cent on the increased investment necessary.

Before concluding it may be of interest to describe briefly the newer and more efficient hot blast stoves referred to, and to cite certain performance figures pertinent thereto. The most widely applied

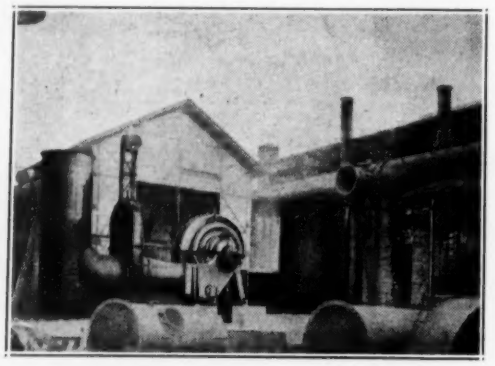

FIG. 9—Theisen Disintegrator Scrubber for Blast Furnace Gas, Outside Installation.

type of stove checker system in new or reconstructed stove work abroad is the invention of Schiffer and Strack of Muenchen, Germany, the interests in this country being held by Freyn Engineering Company of Chicago. The principle of the Strack stove checker system is to provide a variation in the size of the flue openings, progressively through the stove, having heat transfer rates that compensate for the decreasing temperatures of the hot combustion gases as they pass through the stove in one direction, and the increasing temperature of the furnace blast as it passes, later on, through the stove in the opposite direction. (Fig. 2). As in boiler tubes, the heat transfer rate varies inversely with the diameter, so in checker openings. In boiler tubes, for example, the rates are:

4 in. tube	5.32 B.t.u. per sq. ft. per hr. per deg. temp. diff.
3 in. tube	6.34 B.t.u. per sq. ft. per hr. per deg. temp. diff.
2 in. tube	8.40 B.t.u. per sq. ft. per hr. per deg. temp. diff.
1 in. tube	14.60 B.t.u. per sq. ft. per hr. per deg. temp. diff.

Hence, in the upper zone of the checker column, where temperatures are high, and degrees differ in temperature between gases and brick provides a considerable heat head, an 8 in. diameter flue is used.

Some distance below, after the "edge" has been taken off the temperature of the gases, the flues are 3 in. in diameter, the rate of heat transfer increasing by virtue of the smaller diameter, and compensating for the lower temperature head between gases and brick. The zone of 3 in. flues is relatively short and is succeeded by quite small flues of 1¾ in. diameter. This third zone occupies the greater portion of the checker column, and it is here that a large proportion of the heat transfer work is done by virtue of the highest transfer rate obtaining to the small diameter flues.

As shown in the figure, a much larger area of heating surface is secured in the Strack design of stove than is possible in the conventional lay of, say, 4 in. square flues and 2½ in. brick walls. The amount of heating area and the rate of heat transfer are most important factors in the efficiency of a hot blast stove. Comparative performance data is indicated on the figure showing the distribution of the gross heat supplied to stoves of the conventional type and the Strack design respectively. These performance data are based on a four-stove battery of conventional type and a three-stove battery of Strack design. The structures shown are diagrammatic only. Actually, the exterior dimensions might be of the order 105 ft. high by 22 ft. diameter.

Figure 3 shows the brick tiles constituting the checkers in a Strack stove; the single 8 in. flue for the top portion of the checker column; the 3 in. flue for the intermediate section, incorporating seven tubes in a tile; and the 1¾ in. flue for the lower portion of the checker column, with nineteen tubes embodied in a tile. These tiles are hexagonal, which is the only shape which can be laid up with more than four faces of contact. (Fig. 4). Consequently, in a stove they form a most sturdy and undistortable checker structure.

The German Society of Iron & Steel Engineers has investigated this type of stove and approves it. Among the many installations of Strack checkers are such German plants as Hoerde, Hoesch, Hattingen, Arbed, Gutehoffnungshutte, and Krupp-Essen.

A few references to various means for blast furnace gas cleaning may be of interest. Figure 5 is a cross-sectional view of a static tower washer for bringing the gas to a dust content of 0.2 grains per cu. ft. It is followed by the heat exchanger depicted in Figure 6, and shown diagrammatically in Figure 7. A similar form of tower washer, somewhat

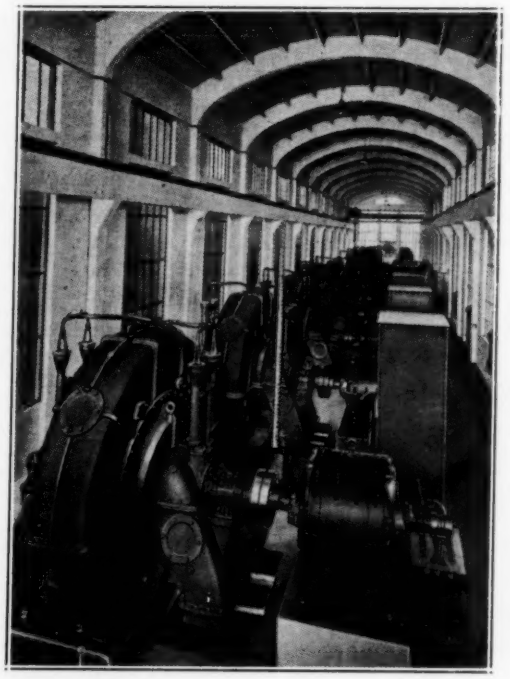

FIG. 10—Theisen Disintegrator Scrubber, Inside Installation.

smaller perhaps, may be used to precool the gas before intensive washing in a Theisen Disintegrator Scrubber, which is shown diagrammatically in Figure 8. The principle of cleaning the disintegrator is the extremely intimate intermingling of water (fed in through syphon tubes) and the dust-bearing gas, by means of rapidly revolving baskets of bars passing between similar baskets of stationary bars. The latter are shown in heavy black lines. Specifications

in power and water input for Theisen Disintegrators are as follows:

Gas cleanliness, grains per cu. ft.	.04	.01	.005
Power input per M. c.f.m. gas, hp.	3 5	5.0	6.0
Water required per M. cu. ft. gas, gal.	7.0	7.5	8.0

Installations of Theisen design are today washing 7,000,000 cu. ft. gas per minute. During 1927-1928. twenty-eight plant installations were made, with forty-six disintegrator units to handle 925,000 c.f.m. gas equivalent to a daily pig iron output of 9,000 tons. By far, a greater proportion of refined blast furnace gas is conditioned in this way than in any other. Several installations are shown in Figs. 9 and 10.

SUMMARY

Underfiring of coke ovens offers the most attractive applications of blast furnace gas. Its advantage is contingent upon market possibilities outside the plant for selling the coke oven gas thereby released, to industrial and domestic uses. There is a very high ratio between the value of the blast furnace gas, and the cost of conditioning it for oven use.

Use of blast furnace gas in steel heating furnaces is pyrometrically practicable and financially attractive. A safe ratio exists between the fuel value of the gas and the conditioning cost.

Blast furnace gas is good fuel under boilers. However, its return in boiler coal replacement value is not apt to be very high, and judicious consideration must be given the matter of the cost involved in conditioning the gas.

In the heating of furnace wind in hot blast stoves, blast furnace gas finds its most essential and profitable utility. Expenditures for proper conditioning are well repaid. It is in stove use that considerable economies have recently developed, leading to the release of additional quantities for other profitable uses.

	Gross value as fired	Cost of appropriate conditioning		Net value as fired	Required cleanliness
	$ per million B.t.u.	$ per million B.t.u.	Ratio	$ per million B.t.u	Grains per cu. ft.
Boilers:					
Replaces $3 coal (as fired)	$0.13	$0.03 (approx.)	4:1	$0.10	0.20 (dry) 0.04 (wet)
Heating Furnaces:					
Replaces $5 producer coal (as gasified)	0.21	0.04	5:1	0.17	0.04
Coke Ovens:					
Replaces coke oven gas:					
(a) for replacement of $5 producer coal (as gasified)	0.19	0.05	4:1	0.14	0.01
(b) for sale at 22c per M. cu. ft. (equivalent $11.00 coal(	0.40	0.05	8:1	0.35	0.01
Stoves:					
Indispensable	0.90	0.05	18:1	0.85	0.01

FIG. 11

EVALUATION OF BLAST FURNACE GAS

Items of Interest

Mr. J. H. Van Campen has resigned his position as Chief Engineer of the E. W. Bliss Company at Salem, Ohio, to accept a position with the Warren Plant of the Republic Iron & Steel Company at Warren, Ohio. Mr. Van Campen will be Chief Engineer of this plant. Mr. Van Campen comes to the Warren Plant with many years of operating steel mill experience to his credit. He is an active member of the Association of Iron & Steel Electrical Engineers and has contributed many valuable papers to this Association.

Mr. Jackson Brown, Jr., 701 Kittridge Building, Denver, Colo., is representing the Roller-Smith Company in Colorado, Utah, Wyoming and Northern New Mexico.

J. M. Livingston, formerly sales manager for Electric Power Equipment Company of Philadelphia, has removed to Chicago, having become associated with Schweitzer and Conrad, Inc., in the capacity of sales manager. Mr. Livingston joined the Elpeco organization immediately after his discharge from the A. E. F. and prior to his service in France, was for five years in the sales department of the Westinghouse Electric & Manufacturing Company at Philadelphia.

It is with regret that we announce the death of Mr. C. H. Cochran, an Associate Member of the A. I. & S. E. E. for the past sixteen years, who died Saturday, March 31. Mr. Cochran at the time of his death was connected with the Philadelphia office of the General Electric Company in the capacity of Sales Engineer.

J. A. Clauss for the past three years Chief Engineer of the Trumbull Steel Company, now the Warren Works of the Republic Iron & Steel, has resigned to accept the position of Chief Engineer of the Great Lakes Steel Corporation at Detroit, Mich.

SKF Industries, Inc., 40 East Thirty-fourth street, New York, announces that the Buffalo, Detroit and San Francisco District Offices of the company are now located in new headquarters to better serve their customers. The personnel of the various offices remains the same. The Buffalo office has moved from 517 Manufacturers and Traders Building to Main and Genesee streets; Detroit from 6520 Cass avenue to 2820 East Grand boulevard; San Francisco from 115 New Montgomery street to 221 Eleventh street.

W. F. Reese for the past fourteen years Electrical Engineer for the Trumbull Steel Company, now the Warren Works of the Republic Iron & Steel Company, has resigned to accept the position of Electrical Engineer with the Great Lakes Steel Corporation at Detroit, Mich. Previous to his going to the Trumbull Company, he was Electrical Engineer with the Weirton Steel Company. Mr. Reese is an active member of the Association of Iron & Steel Electrical Engineers.

Stimple and Ward Company of Pittsburgh, Pa., have been appointed "Service Representatives" for the Black and Decker Mfg. Company and the Van Dorn Electric Tool Company in this district.

S. C. Cozad for thirteen years Field Engineer for the Trumbull Steel Company, now the Warren Works of the Republic Iron & Steel Company, has resigned to accept the position of Field Engineer with the Great Lakes Steel Corporation at Detroit, Mich. He is a graduate of Ohio State University and was previous to his coming to Trumbull Steel Company Field Engineer at the Lowellville plant of the Youngstown Iron & Steel Company. He was also connected with the civil engineering departments of the Pittsburgh Crucible Steel Company at Midland and the Allegheny Steel Company.

The Brown Instrument Company announces the appointment of two Vice Presidents as follows:

Charles H. Kerr, Vice President and General Manager.

George W. Keller, Vice President and General Sales Manager.

R. M. Hughes of the engineering department of the Trumbull Steel Company, now the Warren Works of the Republic Iron & Steel Company, has resigned to accept the position of Chief Draftsman with the Great Lakes Steel Corporation at Detroit, Mich. Previous to his coming to the Trumbull Company, he was employed in the drafting department of the Republic Iron & Steel Company at Youngstown, the Koppers Company, American Smelting & Refining Company, William B. Pollock Company and the Youngstown Sheet & Tube Company.

The Square D Company of Detroit, Mich., and Peru, Ind., and the Industrial Controller Company of Milwaukee, Wis., have been united. Henceforth the two companies will be conducted under one management and will be known as the Square D Company.

The Trumbull Electric Manufacturing Company of Plainville, Conn., have developed a new Polyphase Meter Service Switch. The blade construction provides a double break, materially increasing the current interrupting capacity and decreasing the size of the slate and box. Meter testing type is provided with removable test links which, together with fuses and blades are all mounted on the top of a single slate, easily accessible for testing or inspection. This design is furnished 30-200 Amps., 230 Volts, alternating current.

A new booklet on Motor Maintenance Specialties has been issued by the Martindale Electric Company, Cleveland, O. Copy of Catalogue No. 12 will be sent to interested parties on request.

The Brown Instrument Company of Philadelphia, Pa., are distributing a new booklet entitled "Power Plant Instrument Data Book." It shows 105 applications of instruments to the Steam Power Plant. Copy will be sent on request.

The Delta Star Electric Company of Chicago, Ill., have issued a new publication No. 57. It is a description of outstanding substation development and copy of this publication may be had on request.

A new booklet entitled "Type K Underfeed Stoker" is being distributed by the Combustion Engineering Corporation, New York. A copy of this booklet will be sent to all interested parties on request.

The Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., have issued a new booklet on "Type S. Control and Protective Panels for Crane Service." Copy can be obtained by writing to Westinghouse Company.

The Geo. D. Whitcomb Company are distributing a new booklet entitled "Locomotives with Internal Combustion Engine Drive." Copy can be obtained by writing to this concern at Rochelle, Ill.

The Holophane Company of New York have issued a nem booklet entitled "The Lighting of Modern Office Buildings," and copy will be sent to all interested parties on request.

The Henry N. Muller Company of Pittsburgh have been appointed representatives in the Pittsburgh District of the Burndy Engineering Company, Inc., manufacturers of high tension electrical equipment.

A new company, The Cooper-Bessemer Corporation, representing a combination of The C. & G. Cooper Company and The Bessemer Gas Engine Company, has been announced. E. J. Fithian, President of The Bessemer Gas Engine Company, will be Chairman of the Board, and B. B. Williams, President of The C. & G. Cooper Company, will be President and General Manager of the new corporation. The remaining officers will be chosen from the active executives of both companies.

AMERICAN ENGINEERS ENGAGED BY RUSSIAN GOVERNMENT

A new agreement providing for technical services has been consummated between the Soviet Government and Freyn Engineering Company of Chicago. By the terms of this agreement the Freyn Engineering Company will send to Leningrad a group of engineers and specialists who will co-operate with Gipromez, the State Institute for Projecting New Metal Works, located at Leningrad, U. S. S. R., in the planning, designing and construction of new iron and steel plants, as well as in the reconstruction and modernization of existing metallurgical plants.

The new agreement was signed on March 2, 1929, at the offices of The Amtorg Trading Corporation in New York, by H. J. Freyn, President, and L. T. Shorley, Secretary and Treasurer, of the Freyn Engineering Company, and by Valery I. Mezhlauk, Chairman of Gipromez and Vice Chairman of the Supreme Council of National Economy of the U. S. S. R.

The group of Freyn engineers will sail from New York about the middle of April, and will begin work in Leningrad on May 1. They will be in charge of L. E. L. Thomas, Vice President of Freyn Engineering Company, who is now on his way back from Leningrad where he has completed detail arrangements for the extended sojourn of the group of engineers.

Mr. Gordon Fox, an active member of the Association of Iron & Steel Electrical Engineers and Secretary of the Chicago District Section of the A. I. & S. E. E., will be a member of this party.

The program of the Soviet Government for the ensuing five-year period calls for the planning and construction of ten new iron and steel works, as well as the extensive remodeling of old plants. The total estimated value of the investments to be made in the iron and steel industry alone, amounts to over one billion dollars.

The Freyn company will co-operate in this huge task by giving to the Soviet Union the benefit of its American knowledge and experience. The group, which is to form the nucleus around which it is expected a larger organization will be built up, has been selected and will comprise specialists for coke oven plants, blast furnaces, open hearth and Bessemer plants, rolling mills and power and electric stations.

ARC WELDING TEST

Westinghouse engineers recently tested the strength of arc-welded structures by subjecting an arc welded bedplate to a 50-ton shock test. The bedplate, weighing 4000 lbs. has an overall dimension of approximately 50x100 inches. The structure consists mainly of 162-pound H beams and various pads measuring about 2 inches in thickness.

The welds are all ½-inch fillet welds, about 6 inches in length and the maximum distance between the welds is 10 inches.

In the test a 50-ton weight was allowed to drop on the bedplate from a height of 8 feet. Despite the fact that the bedplate was considerably distorted, only one weld failed under the intense shock. This one weld which failed was at the end of the 2-inch plate on which the weight fell.

BATTLESHIP ARMOR PLATE CUT BY NEW MATERIAL

Cutting 16-inch battleship armor plate, one of the hardest of steels—a feat considered impossible with present day machine tools; tooling porcelain, bakelite and manganese steel, all most difficult tasks with the best tool steel now in use, were among the feats done easily at the Philadelphia Navy Yards recently with a new kind of machine tool material, Carboloy, a product of the research laboratories of the General Electric Company.

The demonstration was an official test of the new material for the Bureau of Engineering of the U. S. Navy. In addition to navy officers, representatives from many shipbuilding and steel companies were present.

The new material is composed of tungsten carbide and cobalt, the carbide being extremely hard and the cobalt giving it the necessary strength for cutting tools. The General Electric Company has been using it in its own shops for more than two years with marked success, not only cutting down the time necessary to complete certain operations from four to ten times, but doing the work at about one-fourth the cost.

HERE'S AN IDEA

A steel company has a novel system of Green Lights throughout the plant, to interest their men in working safely. Some 65 lights have been installed, one in each division. These lights burn as long as the entire division operates safely. Should an accident occur, the light is turned out until the first of the following month.

NEW ACROSS-THE-LINE SWITCH IS OIL-IMMERSED

A new General Electric control device is the CR-2960-SY-105, a small, inexpensive, oil-immersed switch for use in throwing small alternating or direct-current motors across the line. It is a very simple device having a minimum of component parts: A one-piece cast iron cover, including the switch mechanism, and a small, cast-iron tank for the oil.

The molded compound switch base carries the stationary contact stud parts, and the moving contact assembly is mounted on another one-piece moulded part. The contacts are of the silver-to-silver, double-break type. The use of these contacts and of the molded arm eliminates shunts or drum type contacts.

The cover is provided with two mounting holes making the switch suitable for wall mounting. Provision is made for conduit connection by means of an incoming conduit box cast into the cover. The molded switch base is bolted to the cover. The cover has a groove, lined with felt, into which the top of the tank fits, thus providing a tight installation. The tank is held in place by bolts with wing nuts, the handle is of malleable iron.

In designing Lapp Insulators, safety and service are never forgotten

Why the rounded contours on all Lapp Insulators?

COMMON sense tells you that square-end shells are far easier than the rounded to store, handle and burn—because they don't tip so easily. That is the only excuse for the existence of square-end insulators.

However—round contours allow the plastic clay to be streamed over the surface of the mold and forming-tool with the least possible strain, yielding longer life.

Round porcelain shells dry and burn more evenly because the area required for support (which dries and burns slower) is less than on a flat-surfaced shell.

The thickness of the porcelain in round shells is much more uniform at the most vulnerable part of the insulator.

Round surfaces offer greater accommodation to the natural expansion and contraction of insulators in service.

Every one of these factors directly increases the life and effectiveness of an insulator. Any one of them would be ample reason for rounded design—harder to make, but more than justified. Yet Lapp alone is providing the rounded closed-end design.

When the hard way is best, that's the way we make Lapp Insulators. That policy in combination with Vacuum-Process porcelain is paying Lapp users big dividends in 100% service life.

Relative retarded portions of square and round shells in drying before burning and in burning.

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